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ABSTRACT

Across the nation grassroots efforts are springing up in which technical professionals are helping enhance science education. This guide has been prepared to help technical professionals become productively involved in enhancing K-12 science education. It has been prepared by scientists and engineers at Sandia National Laboratories who have been extensively involved in the K-12 science education effort for several years. This guide outlines key principles for conducting effective education outreach activities. Many of these principles are illustrated with examples of activities that proved successful in the Sandia program. This guide is divided into the following sections: (1) Introduction, (2) Science Education: Things You Need to Know Before Getting Involved, (3) Working Effectively With Students, (4) Working Effectively With Teachers, (4) Conducting a Tour of Your Worksite, (5) Sources of Hands-On Science and Math Activity Ideas, and (6) Reader Questionnaire. (JRH)

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SCIENCE EDUCATION IN OUR ELEMENTARY AND SECONDARY SCHOOLS:

A Guide for Technical Professionals Who Want to Help

Sandia National Laboratories

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Sandia National Laboratories

Edited by:
Kenneth H. Eckelmeyer

Produced by:
Shannon M. Lytle

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INTRODUCTION: HOW TO USE THIS GUIDE

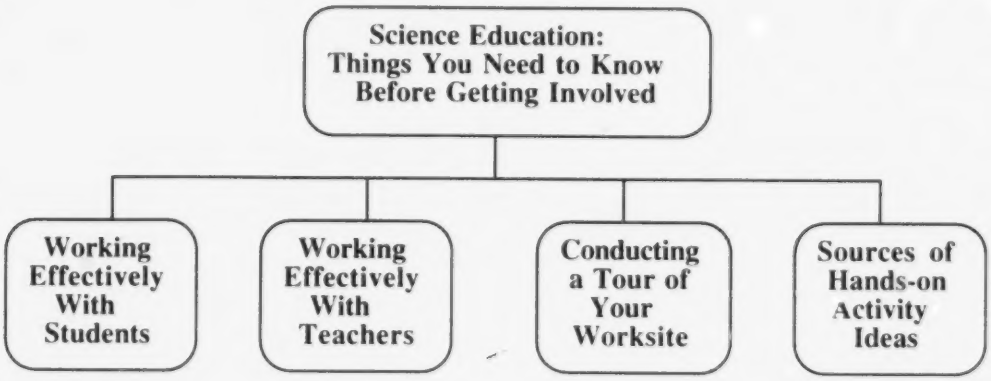
This guide has been prepared to help technical professionals become productively involved in enhancing K-12 science education. It has been prepared by scientists and engineers at Sandia National Laboratories who have been extensively involved in the K-12 science education effort for several years. These individuals relate what they have found to be key principles for conducting effective education outreach activities. Many of these principles are illustrated with examples of activities that proved successful (or less than successful) in the Sandia program.

The guide is organized in a way that will help you access the material which is most pertinent to your particular interests and needs, as shown below. We suggest that everyone read chapter one, which provides general information on science education, students and teachers. You should then proceed to the chapter(s) which are of greatest interest to you.

As you read these chapters you will likely see points you will want to expand upon based on your own experiences, ideas for initiatives you might like to pursue, or thoughts about particular activities you might like to conduct. Jot down these ideas in the margins or on separate note sheets as they come to you, or by tomorrow a good number of them will be forever lost .

We hope that you will find the information contained here to be helpful in your educational outreach efforts.

After you have read this material and employed the principles suggested in it we would appreciate hearing your comments and suggestions. Please send them to us using the reader questionnaire at the end of this guide. Thanks for your help.


Science Education: Things You Need to Know Before Getting Involved
Working Effectively With Students
Working Effectively With Teachers
Conducting a Tour of Your Worksite
Sources of Hands-on Activity Ideas

SCIENCE EDUCATION: THINGS YOU NEED TO KNOW BEFORE GETTING INVOLVED

You Can Make a Difference

So you want to help improve science education? That's terrific! The need is increasingly apparent!

In recent years we have seen a decline in the number of U.S. students who are interested and competent in technical subjects, an erosion of U.S. world leadership in many technology based industries, and a decrease in the technical literacy of our citizenry. All of this has occurred at an inopportune time when our society is becoming increasingly dependent on advanced technology. The bipartisan goal (supported by both Presidents Bush and Clinton) for U.S. students to become first in the world in science and math by the year 2000 is aimed at reversing these trends, but will require a massive effort to achieve.

Fortunately, such an effort is brewing in the science education reform movement. Standards for science education are being formulated. Exciting hands-on inquiry based curriculum and support materials are being developed. Teachers are discovering how to serve as guides to learning, rather than as dispensers of information. The business and professional communities are committing their time and resources. Opportunities abound for concerned individuals to become productively involved.

As a technical professional you can contribute to the science education of today's children, thereby helping ensure the strength of our society in future generations. It is an exceptionally worthwhile cause. The work won't always be easy, but it can be rewarding and fun. Sandia National Laboratories wants to help you in this effort. We are committed to enabling technical professionals to help science come alive for K-12 students and teachers.

Across the nation grassroots efforts are springing up in which technical professionals are helping enhance science education. People from diverse backgrounds are joining in the cause — scientists and engineers, doctors and nurses, university students and retirees. Some of them are working with teachers — helping them access or develop hands-on experiments for use in their classrooms, arranging loans or donations of equipment and resources from companies, and helping them understand science topics they have lacked the confidence to teach. Others are doing science enrichment activities and demonstrations with students to bring curriculum topics to life in exciting ways. Some are working with school boards as advocates for the adoption of hands-on inquiry-based curricula. Others are serving as tutors and mentors. Some are conducting tours of their worksites so teachers and students can see ways in which science is being applied in the real world. Others are helping to organize, conduct, and judge Science Fairs, Invention Conventions, Science Olympiads, and other science-oriented events and contests. Still others are working with out-of-school organizations, such as local science museums, 4-H Clubs, and many other institutions that sponsor after-school or Saturday science activities.

Many of these individuals are enjoying the satisfaction of having a substantial impact on science education, and their efforts are being lauded by local teachers and students. Typical teacher comments to Sandia National Laboratories, where several hundred employees are helping enrich science education throughout the Albuquerque public schools include:

- "My science program has expanded from reading and discussion to building, testing, evaluating, and most of all, making science fun."

- "The students and teachers have greatly increased their interest, excitement, and involvement in science."
- "I find that I am not as hesitant to bring science into the classroom and I am learning right along with the students."
- "This has been the most valuable support program in my nine years as a teacher."
- "[Employee's name] has greatly enhanced our physical science program. His humor, rapport with our students, and ability to demonstrate that science has practical value has stimulated these seventh graders."

And from students:

- "That was the first presentation involving science that I listened to. I really learned some science. Thanks."
- "I really liked the skateboard experiment. It helped me understand 'that equation' (F = Ma)."
- "Those experiments with liquid nitrogen were rad, man."
- "Please come again soon."
- "I'll probably convince my mom to let me go (to college)."

You can become involved in a variety of productive and satisfying ways. But don't jump in unprepared! Your efforts will be more fruitful and enjoyable if you first familiarize yourself with the following background information and capitalize on the lessons learned by others.

Take Advantage of Available Help — Don't Try to Invent Everything Yourself

While a growing number of technical professionals are getting involved and encouraging initiatives are underway in various schools and communities, many of these individuals and initiatives are operating in isolation. As a result, little information is being shared between them, a lot of inefficient "wheel reinvention" is occurring, and many are operating on the steepest part of the learning curve. In addition, there are many other individuals who would like to become involved, but aren't sure how to get started or what to do.

Sandia National Laboratories wants to help improve communication between these initiatives. We believe that by sharing of successes, failures, and lessons learned these grassroots efforts can be greatly enhanced and far more individuals can be productively involved. The material you are reading represents our first attempt at having technical professionals share with one another the principles they have learned about how to conduct effective science enrichment efforts.

This first chapter, "Science Education: What Technical Professionals Need to Know In Preparation for Getting Involved" provides an introduction and background information you should know before embarking on any kind of education initiative. It also suggests a variety of ways in which you might get involved. After you have completed it, the following chapters deal with specific types of involvement. Currently these include: "Working Effectively With Students," "Working Effectively With Teachers," "Conducting a Tour of Your Worksite," and "Sources of Ideas for Hands-on K-12 Science & Math Activities." Additional topics may be added in the future.

These articles have been produced by technical professionals who have been extensively involved in education support. They are designed to provide the key information you need to know to have effective and rewarding experiences. ***Take advantage of what these peers have learned; it's better than re-learning these lessons through difficult experiences.***

Integrate Your Effort With the Science Education Reform Movement

There is broad general agreement on what constitutes quality science education. The current state of educational research in this area is discussed in the reports of numerous organizations. A listing of some of these organizations and their key publications is given at the end of this chapter. You should establish contacts with them, familiarize yourself with their reports, and keep abreast of their continuing activities.

At the risk of oversimplification, the bottom line is that ***we must move from a system which promotes science primarily as recall of factual information and rote computation to one which emphasizes conceptual understanding and logical process skills.*** The traditional methodology in which the teacher communicates information to the students should decrease in favor of hands-on activities in which students conduct investigations, discover key principles, and practice applying them in a variety of situations. This modified approach to science education, which has been practiced by leading teachers for many years, is variously termed "reformed", "constructivist", "inquiry-based", "hands-on", or "discovery-based" learning. The contrasting views of traditional and reformed science education are summarized in the following chart.

	Traditional	*Reformed*
View of students	Passive receivers of new knowledge	Active participants in their construction of new understanding
View of teachers	Dispensers of information	Guides to and clarifiers of discovery experiences
View of knowledge	A static group of facts, principles and procedures which can be recalled	A dynamic body of integrated knowledge which can be applied in a variety of settings, including how to develop further knowledge
View of significant material	Science content: scientific principles, facts, equations, applications, etc.	Science content plus the process of science: experimentation and logical thought
View of who can/should learn science	Primarily above average students destined to become technical professionals	All students: future citizens
View of individual involvement in education	Something you do prior to your career	A lifelong process
View of assessment:	Multiple choice pencil & paper tests measuring mostly recall	Varied assessments integrated into the learning process which also measure student abilities to reason and apply knowledge correctly

A number of national groups have proposed and initiated constructivist programs for K-12 science education. These include the American Association for the Advancement of Science's Project 2061, and the National Science Teachers' Association's Scope, Sequence and Coordination Project.

The recently adopted Goals 2000 Law provides a series of education goals which the President, Congress, and the nation's governors agree we should strive to reach by the turn of the century. These include the goal that "U.S. students will be first in the world in science and mathematics achievement." The Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) has fleshed these out into a prioritized national strategy for science education improvement in their report, "Pathways to Excellence." The National Research Council (NRC) has also been tasked to bring together the scientific and educational communities to develop national standards for basic curriculum content, teaching methods, and assessment of student learning. These will complement the standards for mathematics education developed by the National Council of Teachers of Mathematics (NCTM) in 1989.

Other groups are developing and publishing hands-on curricula, some of which are briefly described in the chapter, "Sources of Ideas for Hands-on Science & Math Activities." The National Science Resources Center (NSRC) has published an extensive guide to outstanding curriculum materials, supplementary resources, and sources of information and resources for elementary school teachers (Science for Children), and is currently engaged in evaluating materials for secondary school teachers. NSRC also sponsors conferences to help facilitate community adoption of hands-on inquiry-based science curricula.

Various groups are also providing guidance on the organizational aspects of forming community partnerships to enhance science education. The National Association of Partners In Education (NAPE) sponsors an annual conference on this topic (not specific to science education). The Triangle Coalition for Science and Technology Education has also published suggestions for organizing and nurturing local partnerships.

Common to virtually all of these efforts is the emphasis on developing a generation of technologically literate citizens who are equipped with critical thinking and analysis skills. U.S. science education in past decades has been directed primarily at producing a modest fraction of highly skilled technical professionals. While we have succeeded in this, the byproduct has been a citizenry which knows very little science and views technology with great suspicion. The new approach is directed, as the title of AAAS's document states, at "Science for All Americans." Research findings indicate that this will be a superior approach for both the future career technologists and the general public.

Adopt a Positive Attitude

As with most endeavors, having a positive impact on science education will depend largely on your ability to interact with, win the respect of, and influence people and organizations.

The worst mistake you can make is to approach teachers, students, or institutions with an arrogant attitude which implies, "You folks have really made a mess of things. I understand the real issues and am riding in on my white horse to show you how to do it right." Even if you're correct (which you probably aren't), you will have stacked the deck in a way that will doom your efforts to almost certain failure. And keep in mind that some teachers and administrators will initially be suspicious of your motives, defensive about their positions, and intimidated by your knowledge of science content, so any hint of arrogance on your part will be greatly amplified in their minds.

Instead, commit yourself to working *with* the institutions and people in your community. Win respect by showing respect. ***Treat teachers as professionals who know a lot more about education and young people than you*** do (they almost surely do). Make it clear that you want to partner with them in ways that will honor their leadership role. Take your lead from the school. Find out about its science curriculum and determine together where and how you might best fit in and contribute. Even if you think that there are substantial flaws in the ways it is doing things, start by working with and supporting its existing program. Commit yourself to working with teachers and/or students where they are. Don't insist that they measure up to (or even concur with) your notions of the ideal.

Two things will result from this approach. First, assuming you do a good job, you will gain their respect and confidence, thereby winning the right to be heard when in the future you make suggestions for change. Second, you'll learn a bit about the realities of the educational process, which will probably modify some of your thoughts and opinions, thereby making you more knowledgeable when you offer future suggestions.

Things You Should Know About Schools and Teachers

Before you get started there are a few basic principles and facts of life about schools and teachers with which you should be familiar. The following observations might not be universally true, but our experience indicates that they are broadly applicable.

Schools aren't autonomous. They have requirements imposed on them by various oversight groups. Typically the state mandates certain competencies for students at each grade level and in each subject area. Frequently the local school board imposes additional requirements. The principal and teachers don't always agree with all of these, but they cannot ignore them. At the end of the year they have to give an account for each student in each subject area. Sometimes they become so narrowly focused on these that they end up "teaching for the test." Their preoccupation with these competencies might make them initially skeptical of your involvement, particularly if it will occupy some class time, because they feel that they can't afford to spend time with things that are not directly tied to the requirements. It is fruitless for you to fight against this. Instead, find out what these competencies are, and tailor your activities to help meet them. This will go a long way toward winning teacher support for your efforts.

In addition to these governing bodies, school employees often feel that hundreds of parents and special interest groups also presume to be their bosses. They can be faced with a wide range of competing demands, expectations, and objections from people and groups who are each convinced that their own point of view is correct. Sometimes they feel "damned if they do and damned if they don't." You will have a difficult time building relationships if you become viewed as part of this problem. Don't be dogmatic!

Schools have very limited funding for purchasing supplies and equipment. But they know a lot about how to stretch a buck and scrounge for things. One of their initial requests will likely be for help in obtaining equipment and supplies. If your company is willing to donate or lend new or used materials this can be a boon for the school. But don't settle for making this your only involvement. We've found some of the most popular items to be simple things such as paper and copier use, educational kits that teachers need to do particular experiments or demonstrations, and small computers that are outdated for scientific purposes. Generally, schools aren't interested in specialized equipment or things that need extensive repair.

Experienced school principals and teachers are frequently idealistic by nature, but tempered with reality through years of experience. Those who have maintained their enthusiasm, flexibility, sense of purpose, and love for the students are to be honored and emulated. They will usually be eager for your involvement and a pleasure to work with. Some, however, will have been ground down over the years, and their enthusiasm, flexibility, sense of purpose, and love for the students will have dimmed. They might be more skeptical of your involvement at first, but can become enthusiastic supporters if, through your commitment, ingenuity, warmth, and useful assistance you help them discover new ways to be effective and rekindle their former excitement. Others will be very set in their ways and simply will not want your involvement. Don't let them get you down, just treat them courteously and work with those who welcome your involvement.

Teachers are pulled in many different directions and are very busy. Try to make their lives simpler, not more complex. Seek to enhance their efforts without imposing a lot of extra demands on their already hectic schedules. Avoid becoming viewed as a time sink or just another person competing for their attention. Be part of the solution, not part of the problem.

The same kinds of cliques, power struggles, and honest differences of opinion that you find in most work settings also exist in school staffs. Try to get along with everyone and avoid becoming identified with one group or point of view. Learn the "do's and don'ts" at your school, and do your best to comply with the school's written and unwritten rules.

Schools get numerous "offers of help," many of which either don't come to fruition or turn out to be very short-lived. This might make them a bit skeptical of you at first. Don't be discouraged. Once you've made good on your commitments and demonstrated to them that *you're* in it with them for the long haul, they'll warm up.

Things You Should Know About Students

Students come in all sizes, shapes, and levels of emotional and intellectual development. A few of the generalities that you need to know, even if you're working primarily with teachers, are outlined here.

Children younger than 10-12 years of age base their social values and find their primary security in their family. As they approach puberty, they not only change physically, but also socially and emotionally. Their peer group becomes increasingly significant in their lives at the expense of family, and they begin to question values and try on new behaviors (some of which seem pretty strange and others of which are genuinely dangerous). This is a natural stage in their learning to interact with and function in society and establish their own value systems (which frequently turn out to be pretty similar to those of their parents). Nonetheless, it is a time of great emotional upheaval for many children and parents alike. For some it settles down by age 15, for others it goes on into their 20s. There's not much that can be done to avoid it — it's just something that young people and their parents have to live through, and educators and youth workers have to accommodate. Don't overreact!

Changes in intellectual development also occur with age. Virtually all ***elementary school children are concrete thinkers — they think in relatively simple terms about what they can see, touch, and detect with their other senses.*** As they mature, most children make the transition to abstract thinking, where they can generalize, project into the future, and deal with less tangible issues. Some people make this intellectual transition around age 11-14, but for many it doesn't occur until they are 15-20. In working with elementary school children, it's essential to be as concrete as possible. Even with high schoolers, it's best to start out with concrete issues and examples and progress to greater levels of abstraction depending on the demonstrated abilities of the students involved.

For example, a concrete way to represent the effects of water on plant growth is to have plants of varying heights and graduated cylinders filled to show how much water each had received arranged together on a table in order of increasing height. One level of abstraction would be to have pictures, rather than real plants and water. Progressively higher levels of abstraction would be to have numerical data, a graph of the data, and an equation representing the effect of water amount on plant growth. An excellent overview of intellectual development is presented in "A Biological Basis for Thinking and Learning", available in print or videotape from Lawrence Hall of Science.

Decline in interest in science and the development of negative attitudes toward it typically occur between the third and eighth grades. These are the critical years for inspiring interest, building basic skills, and avoiding premature burning of bridges. High school is the time to begin focusing more on specific content and future career options.

Applications and hands-on activities are the keys to generating interest and promoting learning! The traditional approach of teaching theory first and applications later is fundamentally unmotivational. Applications that are interesting and relevant to *the students*, as opposed to things that you and your professional peers find interesting, provide the hook to stimulate interest in principles. If you or the teacher wants to arouse students' interest, start with an exciting activity or demonstration.

In addition, programs in which the students are involved in doing hands-on activities are far superior to those in which adults merely show them things or, worse yet, just talk to them. And ***hands-on activities in which students discover things for themselves are the highest quality learning experiences.*** Students forget most of the things their teachers tell them. But when adults lead young people in experiences where they wrestle with an interesting personal observation and then figure it out "by themselves" — those things are remembered forever. ***Seek to be more of a guide to discovery than a conveyor of information and a provider of answers.***

Students exhibit a variety of different learning styles. Some learn science well by listening or reading (auditory and print-oriented learners). They typically do well in our traditional education system. Others learn more effectively by seeing things work (visual learners), by being physically involved in games or activities which simulate scientific phenomena (kinesthetic learners), or by solving problems in groups (group interactive learners). The best learning experiences are those that involve a variety of (ideally all) learning modalities. Don't get caught in the trap of thinking that, just because you are a print-oriented learner, anyone who *really* wants to can learn just by reading books.

Science *process* is at least as important as science content. Students need to be immersed in examining information, developing hypotheses, proposing critical experiments, making observations, collecting data, testing ideas, and developing logical conclusions. These elements should be woven into every content area. If students fail to develop these scientific "habits of the mind" they will become adults whose decisions and positions will be easily swayed by slick advertising or emotional appeals.

An increasing number of children are carrying a lot of heavy personal baggage with them. Things like family disputes and break-ups, substance abuse (by either themselves or their family members), families with little commitment to the importance of education, inadequate or improper food, clothing, or parental support, self-doubts, and the need to impress peers (particularly in the middle school years) weigh heavily on far more youngsters than you might like to believe. Sensitivity to such problems is a valuable asset.

Options for Involvement

There are many ways in which you can contribute, so you'll have to start zeroing in on the type of involvement that's right for you. In doing this you should consider your personal background, skills, and interests, as well as the needs of your community. Some of the key issues you'll need to address involve the people with whom you will primarily interact and their needs. A few of the most significant factors you need to consider are:

District, Teacher, or Student Directed:

Should you concentrate on serving as an advocate for systemic change at the school board level, provide support to teachers or work directly with students? Working for science education reform at the district level provides the greatest leverage. If you do this, however, it is crucial that you be well aware of and connected to the national reform effort, otherwise you could contribute to the problem rather than being part of the solution (see the references at the end of this chapter). In addition, working "in the trenches" with a particular school for a year or so frequently goes a long way toward overcoming naiveté and winning the right to be heard at higher levels.

Working with teachers has some strong advantages. First, most of us are more familiar with and adept at communicating with adults than with children and, hence, do not need to know as much about teaching and learning processes to work with teachers. Second, since each teacher interacts with many students, there is considerable leverage in working with teachers. Third, once you help a teacher become more knowledgeable and comfortable in teaching a science, those enhanced capabilities remain, even after you have gone.

On the other hand, working directly with students enables you to serve as a positive role model. It is particularly important for students to become acquainted with professional role models who are women, ethnic minorities, or disabled. It also provides contacts out of which mentoring relationships can grow, positive images of science and engineering can be fostered, and students can become aware of career opportunities.

Age Level:

Will you concentrate your efforts at the elementary, middle school, or high school level? Elementary school is where initial concepts and attitudes are developed, so there are great opportunities there. Our experience at Sandia National Laboratories suggests that ***the upper elementary grades (3 to 5 or 6) are where most scientists and engineers can have the greatest impact and experience the greatest satisfaction.*** Students begin learning some specific science content, but perhaps the greatest needs are to encourage positive attitudes toward science and develop science process skills, such as experimenting, measuring, observing, and drawing conclusions from information. Many elementary teachers know very little about science and are very eager for any help that is available. Elementary students are curious, exuberant, cute, and relatively unjaded, hence they tend to be easier to work with than their older brothers and sisters.

Middle schools deal with students during their transition from childhood to adulthood. This is where the greatest number of students either catch the spark of excitement for science or intellectually drop out, so there is the potential for great impact in working with this age group. The primary challenge is to help them associate *interesting and relevant* applications with science principles. The physical, emotional, and social changes associated with these in-between years, however, make these students less predictable than either elementary or high schoolers, so they have the reputation of being the most challenging to work with (but for some of us, they're our favorites). Middle school teachers vary widely in their training and knowledge of science content. Some have trained as elementary teachers and have little formal science background, whereas others have trained to be secondary teachers and have extensive knowledge in one or more science disciplines.

High schools typically have science teachers who are well versed in the content they are teaching, but are frequently eager for help in areas such as science applications and new developments, as well as in loans of or assistance with specialized equipment and experiments. High school students who have not burned their bridges in the area of science frequently need help that is more oriented toward understanding content, applications, and relationships between science topics and career and college choices. In lower socioeconomic neighborhoods there are frequently highly motivated students whose families are ill-prepared to help them with academic and career issues who can benefit enormously from mentoring relationships.

Achievement Level:

Perhaps the natural inclination of most scientists and engineers is to work with high achievers. There are opportunities for great payoffs here, for these students will be some of the leaders and trailblazers of the next generation. In addition, they are typically highly motivated, serious about learning, well-behaved, and expressive in their appreciation of your efforts.

At the other extreme are the at-risk students — those who for a variety of family, peer group, socioeconomic, or other reasons are in danger of becoming adults who are drains on our society rather than productive contributors. It is entirely possible that, unless a major portion of this growing group is successfully motivated and enabled to become productive citizens, our societal well-being will be in jeopardy. While the challenges here are great, the needs are enormous, and those whom you help will remember you forever.

Finally, there is the great middle group — those who, like most of us, are neither gifted nor at-risk. Out of this group will logically come the bulk of tomorrow's work force and voters, those who will be responsible for ensuring our well-being when we are retired (what a scary thought!). Will they have the tools to work, live, and vote intelligently in an increasingly complex technological world? You can help ensure that they will.

Cutting across all of these groups, there are particularly outstanding opportunities for engineers and scientists who are women and ethnic minorities to serve as role models for youth, encouraging them to break through the barriers of stereotyping and to overcome the historical underrepresentation of such groups in the technical community.

School-Based versus Out-of-School:

When we think of education, school is typically the first thing that comes to mind. There are, however, numerous other organizations that are becoming increasingly involved in science education. Groups such as 4-H Clubs, Boy Scouts, Girl Scouts, and the like are beginning to expand their traditional roles and placing more emphasis on science. In addition, national organizations like Hands-On-Science and a host of similar local groups that conduct science activities with children and parents are springing up.

The activities of some of these groups are often conducted after school or in the evening, making them easier to schedule than during school hours. Typically, they have a predetermined set of activities to conduct, so less imagination is required and less flexibility is available. While these chapters have been prepared primarily to assist engineers and scientists in working with schools, the same principles apply to working with these other groups.

Taking the First Steps

OK, so you're willing — but how do you get started? Begin by investigating existing programs in which you might participate. ***It is frequently easier to become active in an ongoing program than to start an independent effort from scratch,*** particularly if you have limited experience in working with students or teachers.

One possibility is to look into existing national programs. The National Science Resources Center (NSRC) sponsors conferences to help scientists and engineers learn to serve as advocates for school district adoption of hands-on inquiry-based curricula. Their publication, "Science for Children", also contains a listing of professional societies and museums which sponsor K-12 education programs. The National Research Council's RISE Program (Regional Initiatives in Science Education) promotes opportunities for the involvement of technical professionals in science education. The Institute of Electrical and Electronics Engineers (IEEE) has published a brochure titled "Directory of Volunteer Opportunities in Precollege Math and Science Education for Engineers and Scientists," which gives brief descriptions of a large number of national programs sponsored by professional societies and other groups. Some of these national programs are excellent. Others, however, are fairly narrow in scope, for example promoting only a single profession or discipline. Some have the disadvantage of only sponsoring once-a-year events. Still others impose a fixed program on the schools, rather than seeking to discover and respond to the school's needs.

Alternatively, you can investigate existing programs in your community through your local partnership which oversees the educational outreach activities of professional society chapters. If your area doesn't have such a group, how about organizing one? These groups can serve to focus the efforts of various participants, provide opportunities for training and networking, provide access to resources containing hundreds of ideas for proven activities in various topic areas, provide the supplies and equipment needed to do core programs, interface with the schools to insure that help is being equitably distributed, and provide various kinds of support that facilitate everyone's efforts. Contact the Triangle Coalition for Science and Technology Education or the National Association of Partners In Education (NAPE) for advice on how to organize such a group.

Other ways of finding out about programs in your community include contacting your local school board, your school district's science education coordinator, the local teachers' (or science teachers') organization, the Chamber of Commerce, universities (the college of education as well as various science and engineering departments frequently sponsor science education enhancement programs), museums of science or natural history, groups that are concerned with the interests of underrepresented groups such as women and ethnic minorities, and youth-serving organizations such as 4-H Clubs.

Or, if you really want to do your own thing, you could contact the principal at a local school — perhaps the one your own children attend. Or contact the school superintendent's office and ask the staff to put you in touch with a disadvantaged school — someplace that is less likely to have technical help in its own neighborhood.

Regardless of the type of program you choose, you need to contact the school(s) where you propose to conduct your activities and begin the planning process. It is usually best to meet with the principal first. In this initial contact you should explain your interest and share ways in which you think you might be helpful. After securing approval for your initiative, have the principal discuss your proposed involvement with his or her faculty and identify one or more teachers who are excited about this prospect. Schedule a meeting to get to know them and discuss various possibilities for your involvement. After school or evening typically works best, as teachers usually have short lunch breaks and have lots of things on their minds then. At the meeting, have them tell you about their programs and ways in which they think you could help. Tell them about your interests and the types of activities through which you think you could make a contribution.

Out of this discussion, or perhaps a series of several such discussions and a visit to observe their classes, you should arrive at a tentative plan that everyone supports and a schedule for some starting activity or activities. Don't worry about developing the ultimate plan right away. Get started on something, even if it's small. Put an especially strong effort into your first contribution, and solicit lots of feedback regarding how you could improve and suggestions for continuing activities. This will help you learn more about being effective, plus you'll begin building the relationships that will be crucial to long term success.

In many cases you will need to work with your employer to make arrangements for your education activities, particularly if some of them will occur during your regular work hours. Contact your human resources organization to find out about your company's policies and existing education programs — an increasing number of companies are becoming enthusiastic supporters of such initiatives. Some organizations will allow you to devote a certain number of hours per month to community service activities. Others will match the amount of personal time you spend with company time. Some others will allow you to work non-conventional hours to offset the time that you spend away from work. Talk with your immediate supervisor, get his or her reaction to your proposal, and see what time arrangements can be worked out — your boss' support will be important.

As your activities progress keep your supervisor and company informed. Most organizations are eager to establish good community rapport, and there are few better ways to do this than by helping teachers and students.

Structuring for Success

Before you get too far along, you will want to establish some understandings with the school in order to maximize your effectiveness and avoid misunderstandings. You and the school administration and teacher(s) should reach agreements in areas such as: the purpose and goals of your program, their expectations of you and your expectations of them, how much of your time can they anticipate, what range of activities you are willing to participate in, how much advance notice you will need to be responsive, whether you will have a room to work in and a place to store things, whose responsibility it will be to provide things like supplies and safety equipment, and so on. Try to work out as many of these issues as possible.

In addition, each party's roles and responsibilities should be well understood. Your role might be to provide the teacher with information about applications of the science topics that he or she will be covering, or to do exciting demonstrations with students to stimulate their interest. Don't try to do too much — ***it's better to do a limited amount really well than a lot shoddily.***

You should also establish a plan for assessing the effectiveness of your program. Your employer and other potential sources of funding will be a lot more inclined to support you if you have an assessment plan in place. In addition, the assessment results can help you increase your effectiveness down the road.

The assessment plan doesn't have to be complicated. Develop it based on your purpose and goals. For example, if your objective is to increase teacher use of hands-on science activities, ask teachers to keep track of the numbers of such activities that they employ over the school year and compare how these numbers change from year to year. If your goal is to increase student interest in science, have students complete a questionnaire to assess their attitudes before and after one year of your program. In this case each question should probe some area of attitude, such as: "How do you like science?", "How good are you at science?", "How do you think science affects the world?", "What kinds of people do you think scientists are?", etc. For each question have several possible responses ranging from most to least desirable, for example: "I love it", "I think it's pretty good", "I think it's okay", "I don't like it much", "I hate it." For each question have the students choose the answer that best

describes them. By comparing the percentages of students who give positive answers before and after one year of your program you can determine the extent to which your efforts are having the desired impact.

Keep in mind that baseline data (prior to your program) will frequently be required in order to help you assess your effectiveness. It is important that you develop your assessment approach and administer questionnaires before your program actually gets started. This might seem like an annoyance, but once your activities have started the opportunity to collect unbiased baseline data is frequently gone forever.

In doing assessments it is also good to get information that will help you understand how to improve. Assessment instruments administered following a year of your program should include questions such as: "What things did you like best?", "What parts did you like least?", "What could we do to improve?

In addition to the formal assessment process, you should also set up times with the teachers and/or principal for periodically reviewing your efforts and giving two-way feedback to one another on how things are going and what modifications might be helpful.

Safety is an important element of any science education effort. It is your responsibility not only to be safe, but to model good safety attitudes and practices. Many school systems have lists of forbidden chemicals and other items that are considered hazardous. Find out about them and be sure that you don't violate any regulations. Don't assume that students or teachers understand hazards — explain them! Don't depend on students to follow safety instructions in the absence of adult supervision. Above all, plan your activities carefully! Avoid activities where things could easily go wrong and someone could get hurt. Be sure that you have the necessary safety equipment on-hand to protect people from any possible hazards or to deal with unexpected emergencies.

But if something does go wrong, are you protected from legal liability? It's best to investigate this with your employer and the school. Most companies have insurance which will protect you, unless you've been very careless, provided your effort is officially sanctioned by your employer. Hopefully, it will never become an issue for you, but it's best to be sure that you're covered.

Getting On With It

There's a lot more that could be said, but you are now aware of the key principles you will need to at least get started. As your plans solidify, take advantage of the companion chapters dealing with students, teachers, tours, etc.

Keep in mind that ***improving the education process is a marathon, not a sprint.*** Support is a process. Don't expect to see instant changes. But if you make at least a one year commitment to a particular effort and pursue it consistent with the principles presented here and in the other chapters, you will almost surely see positive results from your efforts and experience the satisfaction of having made an important difference.

Remember particularly the importance of building relationships with the school, doing things in response to its needs, demonstrating a genuine interest in the teachers and students, following through on your commitments, modeling the scientific process, and being safe.

Welcome to the growing cadre of engineers and scientists who are engaged in "the toughest job we ever loved."

Key Organizations, Publications, and Resources in Science Education Reform

National Research Council (NRC), 2101 Constitution Avenue, NW, HA 486, Washington, DC 20418:

"National Science Education Standards (Draft,) 1994 (draft of national standards for science content, teaching professional development, assessment, programs, and systems; final report expected late 1995);

Project RISE (Regional Initiatives in Science Education) (promotes opportunities for technical professionals to help improve science education, publishes free quarterly newsletter, The Catalyst), (202) 334-2110.

American Association for the Advancement of Science (AAAS), 1333 H Street, NW, Washington, DC 20005, (202) 326-6620: Project 2061 (a long-range program for reforming U.S. science education),

"Science for All Americans", 1990 (recommends what understandings and ways of thinking are needed by all citizens in a technologic world — also planning documents for particular disciplines, e.g., science, math, technology, and periodic updates);

"Benchmarks for Science Literacy", 1994 (fleshes out broad goals from "Science for All Americans" into statements of what students should understand at various grade levels); "Science Education News," (free bimonthly newsletter).

National Science Resources Center (NSRC), Suite 880, Capital Gallery, 600 Maryland Avenue, SW, Washington, DC 20024, (202) 287-2063:

"Science for Children", 1988 (an extensive review of outstanding curriculum materials, supplementary resources, and sources of information and assistance for elementary school teachers);

Science Education in the Schools: A Working Conference for Scientists and Engineers (prepares technical professional leaders to be advocates for science education reform in their communities);

Elementary Science Leadership Institute (prepares school district leadership groups to plan and implement science education reform in their districts).

National Center for Improving Science Education (NCISE), 1920 L. Street, Suite 202, Washington, DC 20036, (202) 467-0652:

"The Future of Science in Elementary Schools: Educating Prospective Teachers", 1994;

"Getting Started in Science: A Blueprint for Elementary School Science Education", 1989;

"Education for the Elementary Years: Frameworks for Curriculum and Instruction", 1989;

"Developing and Supporting Teachers for Elementary School Science Education", 1989;

"Assessment in Elementary School Science Education", 1989;

"Building Scientific Literacy: A Blueprint for Science in the Middle Years", 1989;

"Education for the Middle Years: Frameworks for Curriculum and Instruction", 1989;

"Developing and Supporting Teachers for Science Education in the Middle Years", 1989;

"Assessment in Science Education: The Middle Years", 1989;

"The High Stakes of High School Science", 1991.

National Science Teachers' Association (NSTA), 1742 Connecticut Avenue, NW, Washington, DC 20009, (202) 328-5800:

"Project on Scope, Sequence and Coordination: a New Synthesis for Improving Science Education", 1992.

U.S. Department of Education (DoEd), 400 Maryland Avenue, SW, Washington, DC 20202, (202) 732-3000:

"Goals 2000: An Invitation to Your Community", 1994;

"Issues of Curriculum Reform in Science, Mathematics and Higher Order Thinking Across the Disciplines", 1994.

Phi Delta Kappa, 408 N. Union, P.O. Box 789, Bloomington, IN 47402-0789, (812) 339-1156:

"Fastback #376: Hands-On Science Inquiry in the Elementary School, 1994".

National Science Foundation (NSF), 4201 Wilson Boulevard, Arlington, VA 22230, (703) 306-1234:

Funds numerous major programs for state and local systemic reform of science education.

Association for Supervision and Curriculum Development (ASCD), 1250 N. Pitt Street, Alexandria, VA 22314, (703) 549-9110:

"In Search of Understanding: The Case for Constructivist Education", 1993;

"Inspiring Active Learning: A Handbook for Teachers", 1994.

Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), c/o National Aeronautic and Space Administration, 300 E Street, SW, Washington, DC 20546:

"Pathways to Excellence, A Federal Strategy for Science, Mathematics, Engineering, and Technology Education", 1993.

The National Association of Partners In Education (NAPE), 209 Madison Street, Suite 401, Alexandria, VA 22314, (703) 836-4880.

"A Practical Guide to Creating and Managing a Business-Education Partnership";

"A Practical Guide to Creating and Managing School-Community Partnerships".

Triangle Coalition for Science and Technology Education, 5112 Berwyn Road, College Park, MD 20740, (301) 220-0885:

"A Guide for Building an Alliance for Science, Mathematics and Technology Education", 1991;

"A Guide for Planning a Volunteer Program for Science, Mathematics and Technology Education", 1992

Council for Educational Development and Research, 2000 L Street NW, Suite 601, Washington, DC 20036, (202) 223-1593:

"EDTALK: What We Know About Science Teaching and Learning", 1993;

"EDTALK: What We Know About Math Teaching and Learning", 1991.

Lawrence Hall of Science, University of California, Berkeley, CA 94720, (510) 642-1016:

"A Biological Basis for Thinking and Learning", 1990.

National Council of Teachers of Mathematics (NCTM), 1906 Association Drive, Reston, VA 22091, (703) 620-9840:

"Everybody Counts: A Report to the Nation on the Future of Mathematics Education", 1989;

"Curriculum and Evaluation Standards for School Mathematics", 1989;

"Professional Standards for Teaching Mathematics", 1989.

Mathematical Association of America (MAA), 1529 Eighteenth Street, NW, Washington, DC 20036, (202) 387-5200:

"A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics", 1991.

Institute of Electrical and Electronics Engineers (IEEE), 1818 L Street, NW, Suite 1202, Washington DC 20036-5104, (202) 785-0017:

"Directory of Volunteer Opportunities in Precollege Math and Science Education for Engineers and Scientists".

WORKING EFFECTIVELY WITH STUDENTS

There's no doubt about it — impacting students is the bottom line of any educational enrichment effort. Working with students is rewarding because you get to see the "light come on" in their eyes when through a hands-on experiment they discover how something works, or when based on preliminary observations they successfully predict the outcome of an experiment. In addition, interacting with students allows you to serve as a role model and promotes contacts out of which mentoring relationships can grow, positive images of science and engineering can be fostered, and students can become aware of technical career opportunities. Finally, doing science enrichment activities in the classroom enables you to demonstrate to students and teachers alike both the process and applications of science.

To work effectively with students, however, you have to know a bit about what makes them tick, how to relate to them, and how to plan and conduct activities that will be meaningful and memorable learning experiences. Too many technical professionals have the attitude, "I know a lot more about the subject than they do, so working with kids ought to be easy and not require much forethought or preparation." Wrong!!!

Certainly you know more about the subject matter. But the subject isn't all you need to know to conduct a successful in-class activity — not by a long shot! To be effective you also have to understand things such as how your activity fits into the overall teaching plan, what the students already know, what types of additional information and experiences will be meaningful to them, how to conduct the activity so that it will be both interesting and memorable, and how to interact constructively with the students.

This chapter will help you understand some of these key principles. If you learn and practice them, you will greatly improve your chances for having productive and satisfying experiences. If you ignore them, the students will probably be bored and you will become discouraged. It takes time to learn and follow these principles, but the results are worth it.

Social, Emotional and Intellectual Development of Children

In working with students, it's helpful to understand a bit about their stages of social, emotional and intellectual development. Some of this is outlined in the overview chapter, but will be reviewed and expanded upon here.

Social and Emotional Development:

Children younger than age 10-12 base their social values and find their security mainly in their families. Typically, young children from socially and emotionally healthy families are well-adjusted and relatively easy to work with — nice, normal, happy, exuberant kids.

Unfortunately, more and more youngsters don't come from stable homes where positive social values are modeled and their needs for emotional security are met. Things like family disputes and break-ups, substance abuse (by either themselves or other family members), inadequate or improper food, clothing, or parental support, and families with little commitment to the importance of education are more common than most of us would like to believe. Such issues are responsible for a growing number of children of all ages who come to school with a wide range of serious personal problems and are ill prepared to learn. These kids frequently need special intervention to prevent them from growing into adults who pass on similar problems to the next generation. Special education classes are designed to help, but a caring adult volunteer willing to make a commitment to caring for and encouraging such a child can be crucial to his or her development.

As children approach and enter their teens, something remarkable happens — puberty. They not only change physically, but also socially and emotionally. With physical maturation dawns the realization that they can't stay cuddled up in mom and dad's cocoon forever — they're becoming adults, which means that they're going to have to make it in the world on their own. It's simultaneously exciting and terrifying, even to the healthiest and best adjusted kids. With this bag of mixed emotions they make their fledgling efforts toward independence. Their peer group becomes increasingly significant in their lives while the family becomes less so, and they begin to question values and try on new behaviors (often to see what reaction is evoked from their peers). Their time constants for change are remarkably short — one minute they exhibit sophisticated adult behaviors and attitudes, and five minutes later they seem to have socially and emotionally reverted to third grade. It's a time of great emotional upheaval for many children and parents alike, not to mention others who have to interact with them, such as teachers.

Fortunately, this early adolescent period doesn't last forever. It's just a natural stage in their learning to function in society and establish their own values (which frequently end up being similar to those of their parents). While they're in the midst of the turmoil, however, these youngsters have an incredible need for caring adults who will simply *like* them, *assure* them that they're going to turn out great (they are scared to death that they're ugly and/or stupid, and that they will turn out to be misfits), and *help* them develop the skills they'll need to succeed as adults.

By the time they reach 15 or 16, the turmoil is starting to slow down for many, but for some it goes on into their 20s. When they are juniors and seniors in high school most of them are socially and emotionally much more stable, and are well on their way to establishing themselves as adults. At this age, however, they have a great need for respected mature adults who model appropriate behaviors and attitudes, who challenge them intellectually and socially, and who will interact non-judgementally with them as they struggle with difficult issues or questions.

Intellectual Development:

Changes in intellectual development also occur with age. Most elementary school children are *concrete* thinkers. They think in fairly simple terms about things they detect with their senses, i.e., things they can see, touch, hear, and smell. In the early grades they can only deal with and think about things which they can *presently* see and touch. In addition, they can conceptualize only *one attribute or variable* at a time. Consistent with this, they learn to classify things into *major* categories, ordering them by single attributes such as length, size, shape, color, texture, etc..

In later primary grades they can deal with and think about things which they saw or handled *yesterday or last week* but that are not available to see or touch today. In addition, they become able to conceptualize *more than one variable*. This enables them to classify things more complexly into major categories and various *subcategories*, e.g., by shape, and for items of similar shape, by size, color, or texture. Throughout the concrete thinking stage, however, their abilities to conceptualize are limited to *real* things — either ones that are present right now or those that they have experienced previously. Things that they can't see or touch, such as atoms, voltage, and sound waves are very difficult for them to conceptualize, even though they may seem simple to us.

As they mature, most students make the transition to *abstract* thinking, where they can generalize, project into the future, and deal with less tangible issues. In mathematics, ***algebra represents an important transition from the concrete (numbers) to the abstract (symbols).*** Making the leap from specific problems and real numbers to generalized formulations involving x's and y's is a frustrating exercise for those who have not yet begun the transition from concrete to abstract thinking. Some people make this intellectual transition around age 11-14, but for many it takes much longer, and some remain concrete thinkers throughout life.

In working with elementary school children, it's essential to be as concrete as possible. Even with high schoolers (not to mention adults), it's best to start out with concrete activities and progress to greater levels of

abstraction, depending on the demonstrated abilities of the students involved. For example, the most concrete way to represent the effects of water on plant growth is to display plants of varying heights and graduated cylinders showing how much water each plant received arranged together on a table in order of increasing plant height. One level of abstraction would be to show pictures rather than real plants. Progressively higher levels of abstraction would involve numerical data, a graph of the data, and an algebraic equation representing the effect of water amount on plant growth.

"A Biological Basis of Thinking," provides an excellent summary of the stages of cognitive development. It can be obtained in either videotape or print form from Lawrence Hall of Science.

Attitudes Toward Science:

When they enter school, children are usually fascinated by the world around them. They typically have great curiosity about and positive attitudes toward science. Starting in about the third grade and continuing through about the eighth grade, however, increasing numbers of students lose interest in, and develop negative attitudes toward science. Thus, third through eighth grade is a critical time for inspiring interest, building basic skills, and avoiding premature burning of bridges.

By the time they reach high school the student population has pretty much become bimodal with respect to attitudes about science. A substantial percentage of students have essentially lost interest in and tuned out of science and math. It is difficult to re-engage these students in the context of traditional academic classes. Perhaps the best bet is to attempt to rekindle their interests through the back door of technology. A good bit of *applied* science and math can be incorporated into industrial arts and other applied classes. Some uninterested students learn key science and math concepts very effectively when they are directly tied to solving specific hands-on problems.

On the other hand, some high schoolers have retained their interest in science and have developed the tools needed to continue expanding their understanding. For them, high school is the time to begin focusing more on specific content and applications of science with an eye toward career options.

Principles for Maximized Learning

In addition to understanding the basics of social, emotional, and intellectual development, you should also be familiar with the elements of effective learning experiences.

Learning vs. Memorization:

Educators make an important distinction between *learning and memorization*. ***Learning involves assimilation of new knowledge in a way that it is understood and can be applied.*** Memorization, on the other hand, does not necessarily involve understanding and requires only that information be *recalled*, not applied.

Sometimes our society mistakes memorization for learning. Perhaps this is because recall is easier to test for and quantify. But successful recall of facts does not necessarily imply understanding or application ability. It is true that students who have learned about a topic will typically remember facts relating to it. But the remembrance of these facts is more a side-effect of learning having occurred than its essence. Facts that have simply been memorized, but which have not been integrated into a system of understanding and which cannot be appropriately applied really aren't very useful (except perhaps for passing tests). Interestingly, they usually aren't remembered for very long either. Clearly, the goal of education should be learning, not just memorization.

Regarding the learning of science, educators point out that each person has certain generalized mental schemes

about how things in nature work. Typically these schemes have been constructed to be consistent with the natural events we have experienced and are familiar with. Young students have very simplistic schemes — birds and winged insects fly, therefore wings enable flight. Ph.D. scientists have more complex schemes, but like the young child's they are constructed to be consistent with and explain observed behavior. No one's schemes, however, represent the ultimate and complete truth about nature — at best each represents partial, but incomplete, understanding.

Educators believe that the first step in the learning process occurs when students encounter something they cannot explain in terms of their current schemes. This step is inherently student-centered. Teachers can provide interesting activities, materials, and direction to promote these encounters, but the experiences of the students are the key events. These "unexplainable" encounters might initially cause some frustration, but they also pave the way for the second step in the learning process. Here the students re-evaluate their schemes in an effort to modify and make them consistent with their experiences and observations. In this stage the teacher helps the students organize their observations, understand the shortcomings of their previous concepts, develop new schemes that correctly account for their recent experiences, and learn the language associated with the new concepts. In essence, the teacher guides the students in the discovery of new or expanded schemes. In the third step, the students apply the new concepts to a variety of problems. This reinforces the concepts, ensures real understanding, and provides practice in application.

If the student is inherently incapable of understanding the new concept, for example because it requires abstract thinking skills that have not yet been developed, frustration occurs. Placed in this situation, highly motivated students with strong desires to please parents and teachers will try to memorize enough to score well on tests, but lacking real understanding, will quickly forget what they have memorized. Other students will lose interest and give up, concluding that science is very hard and that they just can't learn it.

In addition to being consistent with the students' level of intellectual development, ***some of the common denominators of great learning experiences are: they are fun and exciting, they involve hands-on activities in which the students discover the underlying principles for themselves, they integrate applications that are relevant to the students into the learning of principles and theory,*** they appeal to students having a variety of learning styles, they encourage the student to integrate new knowledge with his or her existing body of knowledge and to practice applying it, and they are designed so that nearly all of the students experience success. Let's consider each of these briefly.

Fun and Excitement:

If you want to get students' attention, you better do something that involves fun and excitement. Today's kids are accustomed to experiences that involve or portray nearly continuous action and virtually instant gratification — just check out the popular video arcades, Saturday morning cartoons, movies, and rock videos. Many young have become conditioned to expect life to provide nearly continuous fun and excitement. As a result, they are easily bored and inclined toward activities that provide short-term satisfaction, rather than those that require short-term discipline in order to realize long-term rewards. While most of us would agree that this is unfortunate, it is a fact of life which we need to recognize and deal with if we are going to work effectively with students. The fact is that if we want students to develop favorable impressions of science, we better incorporate fun and excitement in the learning process.

For example, in a middle and high school program on chemical bonding we examine the effects of temperature on the properties of rubber tubing. After demonstrating its normally flexible behavior we cool it in liquid nitrogen and then challenge students to bend it. At first they conclude that it is very strong, but when they exert sufficient force it shatters dramatically into thousands of tiny pieces, which fly all over the room (safety glasses are a must). This typically creates great interest, and soon students are selecting other things that they want to test and are hypothesizing about how various materials will behave at very low temperatures. This provides a great

lead-in to a discussion of the molecular structure of polymers, and how materials scientists engineer materials with different properties by varying chemical bonding and atomic arrangements.

Please don't misunderstand — this doesn't mean that there is no place for disciplines such as study, memorization, and drill. However, in order to get students interested and committed to these disciplines it is crucial that fun and exciting activities be included with each science topic. You can play a key role in the educational process by helping to provide such activities. While teachers are typically better equipped to do the actual instruction, your enthusiasm for science and its applications provides a great opportunity for you to generate the excitement needed to ignite or fan the flame of interest among their students.

Hands-On, Discovery-Based:

One of the worst ways to generate excitement is by giving a lecture. Nearly all of us find *doing* things more interesting and exciting than *seeing* things or, worse yet, *listening* to things. Kids have shorter attention spans than adults, so they are much less tolerant of lecture formats than we are. Activities in which everyone becomes personally involved in thought-provoking ways provide a much more interesting format in which far more learning occurs. ***Hands-on activities designed to enable the students to discover explanations and underlying principles by themselves provide some of the greatest learning experiences.***

Once after conducting the rubber-hose-in-liquid-nitrogen activity with several classes of seventh graders, a young lady from one of the classes called and asked if I could provide some liquid nitrogen for her science fair experiment on how rapidly different foods froze and thawed out. After agreeing and setting a time and place for the experiment, I encouraged her to invite a few of her friends (by reminding them that this promised to be a lot of fun).

When the big day arrived, the four of us tested apples, oranges, bananas, marshmallows and dinner rolls. After running one sample of each material and finding a wide range of cooling rates, I asked, "I wonder what made some things get cold quickly and others take a long time?" They talked among themselves about this. (The reason I wanted several of them there was because a single student might hesitate to speculate with me, thinking that I know the right answer and that she would be embarrassed if she guessed wrong.) When they got around to the idea that not all of the samples were the same size, I asked, "Is there a better way we could have done the experiment?" After discussing this a bit, they decided to repeat the experiment using samples of equal mass. (Fortunately, I had a balance in my car!)

This time they found that the three fruits all cooled at the same rate, while the marshmallow and dinner roll took much longer. When they recognized this grouping, I asked, "I wonder what it is that apples, oranges, and bananas have in common that's different from marshmallows and dinner rolls?" After discussing this for a while, they hit upon the idea that the three fruits contained a lot of water while the other two items were very dry. "When a scientist has an idea like that it's called a hypothesis," I commented. "Then she or he tries to think up an additional experiment to test their hypothesis — to see if it is correct." After thinking for a while, the girls decided to put an equal mass of water in a vegetable bag, place this in the liquid nitrogen, and measure its cooling rate. The results confirmed their hypothesis.

During that hour and a half they *discovered for themselves* the concepts of controlling variables, grouping data, constructing hypotheses, and designing critical experiments to test hypotheses. And since they *discovered* them, they'll *remember* them. All I did was ask leading questions at appropriate times to guide their thought processes. If I had told them at the outset to make all of the samples the same size they would have done it, but by the next day they likely would have forgotten the concept and importance of controlling variables.

Leading kids just enough that they make the important discoveries for themselves is education at

its best. Think back over your own experiences. If you're like me, you've forgotten most of things that people told you, but the things you discovered "for yourself" are indelibly etched on your memory.

Combine Science Process With Science Content:

It's important for students to learn science content: electricity and magnetism, the water cycle, photosynthesis, etc. But it's even more important for them to develop scientific habits of the mind: critically examining claims, developing and conducting experiments to test ideas and hypotheses, making observations and measurements, sorting through and organizing information, reasoning logically to derive valid conclusions from their observations and data, etc. Many of the students will be able to become successful adults without knowing much about science content, but *all* of them will have to possess logical thinking skills to be rational shoppers, intelligent voters, and full participants in adult society. How will they develop these skills? By practicing them. And what better setting to practice them than in the context of science — the discipline which is based on inquiry, critical examination, experimental inquiry, and rational conclusions developed from unbiased measurements.

Interestingly, educational research shows that both science content and science process are best learned in conjunction with one another. In other words, we best learn the things we reason through and "discover" for ourselves; we also best learn logical thinking skills in the process of applying them to concrete problems.

Consider the apples-and-marshmallows-in-liquid-nitrogen activity described above. It dealt with science content areas such as temperature, states of matter, phase changes, and thermal conductivity. In addition, it involved the students in science process: developing and refining experiments, making measurements, reasoning logically about the implications of the data, and debating and agreeing on rational conclusions. Teaching science in the context of inquiry-based activities promotes highly effective learning of both science content and science process.

Principles and Applications:

For most people, experience with practical applications provides the incentive and motivation for learning about theory and principles. Once I had quenched steel and discovered its dramatic effects on hardness and strength I developed an interest in understanding why. I am convinced that if the theories of diffusional and martensitic phase transformations had been presented to me before I had this applications-oriented frame of reference, I would have found them both boring and confusing. Since I was familiar with their practical applications, however, I not only found these topics fascinating, but also was able to discipline myself to struggle through the difficult parts and master them.

Too often, however, our educational paradigm is to teach principles first, with applications to follow — if time permits. Could this be the reason so many of our students are bored and uninterested in science — because they see no relationship between the things they are learning in class and the real world in which they live? You bet! ***The traditional approach of teaching theory first and applications later is fundamentally unmotivational.*** Applications that are interesting and relevant *to the students* (as opposed to things that you and your professional peers find interesting) can provide the hook to stimulate interest in principles.

One good applications-oriented math exercise asks each group of students to figure out how high the school (or something else) is using a cardboard tube from a roll of toilet paper or paper towels. Each group "calibrates" its tube by standing back various distances from a meter scale on the wall and determines how the vertical field of view seen through the tube changes as a function of distance. The students then go outside and see how far they have to get back from the school to just get it in the field of view. From this information each group computes the height of the school. It can be a proportions problem, a graphing problem, or a trigonometry problem, depending on what is being covered in class. The beauty of the exercise is that it develops the subject matter in the context of an *application that is real to the students*, rather than just as a rote manipulation or abstraction.

Sharing how the material they are covering in their classes relates to interesting (and understandable) applications from your work can also stimulate interest. As professional scientists and engineers we are ideally positioned to provide the applications link that motivates students to want to understand scientific principles.

Learning Styles:

Students exhibit a variety of different learning styles. Some learn well by listening or reading (auditory and print-oriented learners). They typically do well in our traditional education system, which is structured consistent with their natural style of learning. Others learn more effectively by seeing things work (visual learners), by being physically involved in games or activities that simulate scientific phenomena (kinesthetic learners), or by solving problems in groups (group interactive learners). The best learning experiences are those that involve a variety (ideally all) learning modalities. Remember — just because *you* have a particular learning style doesn't mean that all students learn best in the same way.

A common component of a middle school study of solids, liquids and gases covers how the atoms or molecules are arranged and bonded in each of these states of matter. A conventional way of teaching this might be to have students read about it and to explain it to them orally (print-oriented and auditory learning experiences).

In a more complete and balanced educational program this could be supplemented by visual and kinesthetic experiences where the students see and handle ping-pong ball models — balls glued together for the solid, unglued but contained in a vegetable bag for the liquid, unglued and uncontained for the gas. Another kinesthetic experience would have the students pretend that they are each atoms and to behave as if they were first a solid: everyone holds hands, then a liquid: everyone holds hands, but continually changes partners, in sort of a disorganized square dance, and then a gas: everyone lets go of one another and moves in straight lines around the room until they run into and bounce off of something or someone. A group interactive activity could involve teams of students trying to estimate how many bonds in a liquid are broken at any one time based on the heats of fusion and vaporization.

Integration and Application:

Students need to not only absorb new information, but also to integrate it with their existing knowledge and experiences, and to practice applying it. Only after they have done these things is the new information likely to be retained and available for their use.

When I work with seventh grade physical science classes it's amazing how many opportunities I find to connect new material with activities we have done in the past. Activities early in the semester involve Newton's Law (force and acceleration) and buoyancy (floating and sinking in liquids and gases). Later in the semester when we are doing activities involving states of matter we cool balloons full of various gases in liquid nitrogen. With just a little leading the students are able to go back to Newton's Law and both predict and explain why the balloon shrinks when the temperature is lowered and the molecules slow down. Similarly, when given time to hypothesize whether a helium-filled balloon will rise or fall after being immersed in liquid nitrogen, they hearken back to the density activities and conclude that the balloon might fall — until it warms up, whereupon it will expand and float.

These integration experiences are crucial not only to the learning of past and present material, but also provide practice for the application of knowledge in the real world where very few high-level tasks require simply the recall of the "correct" answer. And the excitement in their eyes when their predictions are confirmed by experiment is a priceless reward for us who dedicate our time to them.

Repetitive practice in applying new knowledge is also crucial to the learning process. All of us have had the experience of reading about something and thinking that we understand it — and then realizing when we try to apply it how limited our understanding really is. Useful knowledge is developed in the process of applying it —

over and over again — to a variety of problems. This practice aspect, however, is very time consuming, so it is usually not possible for us to incorporate this into our programs because we spend a limited amount of time with the students. By integrating our activities with the topics being covered by the teacher, however, the teacher is able to do follow-up activities and provide a more complete learning experience.

Success-Oriented:

One of the greatest temptations of the technical professional is to develop challenging activities that only the brightest students in the class can understand and relate to. This only reinforces the preconception of many of the youngsters that science is very hard and that they can't do it. Don't get caught in this trap. ***Your goal should be to help 95% of the kids believe that science is interesting and that they can do it!***

Design your activities so that nearly everyone gets involved and experiences success. Experiments that are virtually impossible to mess up, such as making "slime" by mixing together polyvinyl alcohol and borax solutions, are great for young students. In some cases this will mean working in groups rather than individually. You and the teacher might want to meet with group leaders and the brighter students ahead of time to enlist their support as part of the team to ensure that each student gets to participate and develop understanding.

One of the most important things you can do is to help students redefine success in science — as learning something rather than knowing the correct answer at the outset. When I am working with students I frequently ask them to make hypotheses about an experiment we are about to do. Some of them construct correct hypotheses, others incorrect. I then give them an opportunity to explain and discuss their hypotheses with one another. In this process some of the students frequently see flaws in their reasoning and switch camps. Then we do the experiment and discover which hypothesis was correct and discuss why.

Then I congratulate and make a big fuss over the students whose initial hypotheses were *wrong!* I tell them that they participated as *real* scientists, because that's what good scientists do — they make a hypothesis based on their best current understanding, do an experiment to test their hypothesis, and *change their minds* when the results of the experiment indicate that their hypothesis was wrong. Then I share with them that many of my hypotheses at work turn out to be wrong, but that my employer continues to pay me, because out of the incorrect hypotheses comes increased understanding, which eventually leads to some correct hypotheses and the development of improved (in my case) engineering materials.

Coordinating With the Teacher — The Foundation for Success

With the principles of social, emotional, and intellectual development under your belt, and an appreciation for the elements of successful learning experiences, you're now ready to start implementing some specific activities. But don't try to do it on your own, or you'll be overlooking, and possibly alienating, the person who could be your greatest supporter and guide: the students' teacher.

The teacher knows far more than you do about such things as cognitive development, the structure and goals of the curriculum, classroom management, and the abilities, limitations, and learning styles of the students. On the other hand, you might know more about science content and how science is applied in the real world. By working together as a team you can make each other's jobs more productive and interesting. If you and the teacher work independently, or worse yet in competition with one another, your efforts with students are not nearly as likely to be productive.

There are a number of up-front issues you need to discuss with the teacher before beginning to plan a meaningful activity. First and foremost, you need to assure the teacher that you want to assist and supplement his or her efforts, not criticize, belittle, or change what he or she is doing. If the teacher sees you as a threat you will start out with two strikes against you. Your preliminary discussions with the teacher(s) should also include topics such as integration of your activities into the curriculum, determination of your role and how your activities fit in to the overall teaching plan, and understanding what student background knowledge you can anticipate. Let's elaborate a bit on each of these.

Integration Into the Curriculum:

It is important for you to plan your activities to fit into and strengthen the curriculum and overall teaching strategy. ***Activities that are unrelated to what the students are learning in their classes might provide interesting diversions, but those that introduce, reinforce, or illustrate applications of current curriculum topics have far more impact.*** Talk with the teacher and find out when in the semester topics related to your professional interests will be covered and when there might be opportunities for you to do enrichment activities with the students. Then present your activities when they coincide with coverage of the pertinent or related topics in class.

Determining Your Role in the Teaching Plan:

In addition to coordinating your activities with the curriculum, you should also determine with the teacher what role in the teaching process your activity will play and what its goals will be. Very rarely will your activity comprise all of the instruction in a particular topic area.

Occasionally you will be introducing a new topic area. In these cases activities that serve as appetite whetters and curiosity arousers are very appropriate and relatively little time should be spent on in-depth explanations.

Many times your activities will be dealing with real world applications of the principles they have been studying in class. It is essential that these be applications the students can understand and relate to.

Concentrate on activities where you have something to offer that the teacher simply couldn't provide — experience with real world applications, special supplies or equipment, and so on. Avoid activities in which the teacher could easily do everything that you will do. That's the teacher's job and he or she can almost surely do it better than you can.

Understand Student Background and Vocabulary:

Two of the most common mistakes of technical professionals are making incorrect assumptions about students' level of knowledge and using vocabulary that students don't understand. For each activity have the teacher explain to you what background knowledge the students will have and what vocabulary terms have been used in class. Then review your tentative activity plans with the teacher to get a reality check on whether it is at an appropriate level for the students.

Some teachers might worry that they will offend you by offering criticisms of your plan. Try to overcome this by letting the teacher know that you really want the activity to be an outstanding experience for the students, and that constructive criticisms, rather than offending you, will be appreciated as a means of helping you reach that goal.

Go over your planned explanations carefully and get rid of as much technical jargon as possible. Be especially careful to avoid using acronyms. For younger children it is particularly important that you simplify your vocabulary — since technical terms are second nature to us it takes a strong conscious effort to avoid using them in situations where they cause confusion. For technical terms that are essential, prepare to explain them clearly in terms that youngsters can understand. Be sure that the teacher will be present during the activity, and that he or she has your permission to interrupt and/or question you in order to clarify issues that the students are not understanding.

Planning and Preparing Successful Activities

After you've done this preliminary preparation with the teacher and identified a topic area, you're ready to begin fleshing out your plan. Begin by going back over the principles for maximized learning. Keeping in mind the level of intellectual development of the age group, think about potential activities that would be fun and exciting, involve hands-on discovery experiences, demonstrate practical applications that the students can understand and relate to, involve various learning styles, and provide nearly all of the students with a feeling of success and accomplishment.

Tap into the resources listed in "Sources of Ideas for Hands-on K-12 Science & Math Activities" to discover and investigate things that others have done on similar topics. Consider how you might use or adapt one or more of these for part of your program. Put each idea through the screens of age-appropriateness and learning principles, and distill your list down to a few of the best possibilities. The teacher might be very helpful in this process, particularly if you're relatively inexperienced. Then begin to develop an order in which several related activities could be strung together, consistent with the following principles.

Start With a Grabber to Generate Interest and Focus Attention:

Don't assume that the students are going to start out sitting on the edges of their seats just dying for the pearls of wisdom that you're going to drop on them. Your first task is to win their attention. Activities or demonstrations that involve something dramatic or unexpected are terrific for this purpose. Be sure, however, that this introductory activity ties in with the topic at hand because, once you have their attention, you'll want to be able to make a logical transition to your next activity or segment.

When I do a program with middle schoolers on force and acceleration, I start by wrapping up a student volunteer skateboarder (I'll call him Juan) in many layers of bubblewrap packaging material, giving him a bike helmet, putting him onto a skateboard, and running him into the wall (carefully, of course). After that everyone is paying attention! Then I take the bubblewrap off and feint doing the "experiment" over. This leads into an interactive discussion of how the force applied to Juan's body and the suddenness of his change in speed vary with the number of layers of bubblewrap. Out of this the students develop an appreciation for the principle that force scales with the suddenness of change in speed. Only after this "intuitive" understanding has been developed do I present and begin discussions regarding applications of Newton's Law, F = ma.

Design In Clear Connections and Transitions Between Activities:

Many of your programs will involve several activities. It is important that these be clearly connected, not only in your mind, but in the students' minds. Too often we abruptly finish one thing and move on to something else in a way that disrupts continuity, where just a few words of transition would build these activities into a much more coherent whole.

In the middle-school program on Newton's Law, I start with the skateboard activity to generate excitement and develop qualitative understanding. Then I move on to a more quantitative activity where we interactively estimate

the forces applied to humans in accident scenarios that are part of the students' "real world," such as a skier running into a tree or an outfielder running into the wall. After that I progress to a description of how engineers did very similar calculations to determine what damage would occur to a transportation system during a severe accident. I then show a five minute videotape of destructive testing of a few transportation systems (most middle schoolers are "into" destruction). Finally, I explain that we used the few destructive tests to verify our calculations. Once we knew that our calculations were correct we were able to do most of the "testing" by computer rather than having to perform a large number of very expensive "real" crashes. Logical sequencing and good transitions between activities help make the entire program a clear package rather than a series of disconnected activities.

Build from Simple to Complex, Concrete to Abstract:

Start with simple, concrete examples and activities that virtually everyone will readily understand. As students experience these initial successes they will gain the confidence and knowledge that will enable them to tackle progressively more complex and abstract challenges.

Don't, however, try to pack too much into a single session. It's much better to do a little bit well than to attempt to do so much that you end up confusing most of the class. Initially you should look to the teacher for guidance in this area. As you gain more experience you'll start to get the hang of how complex and abstract you can get before you start to lose people, as well as how long various kinds of activities are likely to take.

Not all of your activities should be highly structured. Some of the greatest learning experiences occur during times of purposeful messing around because they provide terrific opportunities for student discovery experiences to occur.

Plan a Strong Closing:

It's good to close with something that enables the kids to prove to themselves that they've learned something. A puzzle, problem, or experiment that they will be able to solve or correctly predict the outcome of works great as a closer. When they get it right, heap on the praise. This will strongly reinforce their learning experience and also pave the way for a positive next visit.

Finish with a positive statement about how much they've learned and encouragement regarding how efforts that they make now will pay dividends in the future, rather than a bland statement like, "That's all I have for today."

In a middle-school program that relates atomic bonding to the properties of engineering materials, I close by having the students hypothesize and explain in terms of molecular structure what will happen if we stretch a rubber band, place it in liquid nitrogen, and then remove it and put it on the overhead projector. Initially, most of them reason that the rubber band stretches by carbon-carbon bond rotation resulting in molecular chain straightening (which we've discussed previously), but that when it is then cooled the carbon-carbon bonds will no longer be able to rotate, so the rubber band will remain stretched when released. Then someone says, "But not forever," and explains that as the material heats up bond rotation will again be possible, so the chains will re-curl and the rubber band will eventually return to its unstretched shape. Pretty soon the whole class agrees, so then we do the experiment. When it happens exactly as they had predicted, I take advantage of the opportunity to complement them on how much they've learned, tell them about the great careers available for chemists and materials scientists, encourage them to continue to take their studies seriously, and tell them how much I'm looking forward to our activities together next month.

The closing also provides an excellent opportunity to encourage them to tell someone who wasn't in the class about what they did and learned. This gives them opportunities to be "the experts", and also makes them think back through the activities and principles, thus fixing them in their minds.

It is also a good time to give each student something from your program to keep, particularly something that can be used to tell their friends or parents about what they did and learned. Just make sure that it's not something that someone could get hurt with.

Know Where You Will Cut If Time Runs Short:

The best-laid programs of mice and men often take longer than expected. You might be able to run a bit over-time in an elementary school where the students don't change classes, but in a middle or high school, when the bell rings you're history.

Plan how much time you expect each segment of your program to take, and keep track of how you are doing relative to your time projection. Know what you can either condense or eliminate if you are running behind schedule. It's almost always better to cut something than to try to squeeze everything into a shorter time, but be careful not to cut an activity in which knowledge or skills that will be needed for a subsequent portion are developed. At all cost, keep time available for your closing activity and comments — these are too important to eliminate.

Plan for and Model Safety:

Go over all your activities and be certain that they're safe, environmentally sound, and don't violate any school guidelines. Make sure that you have the appropriate safety equipment available. Remember, ***your job is not only to be safe, but also to model good safety awareness and environmental consciousness.***

One way I do this is in conjunction with repeatedly emphasizing the theme that scientists and engineers don't primarily memorize facts, but rather do experiments. Each time I do this, I reinforce, usually in the form of a question, that before good scientists do an experiment they think about ways in which it could harm people, property, or the environment, and either take appropriate precautions to avoid such damage or cancel the experiment. The students then participate in projecting the potential dangers in the experiments that we are considering doing together and help determine what precautions need to be taken (or what experiments suggested by classmates are too dangerous to be done).

Reinforcing this theme in repeated visits provides a good learning experience and also helps overcome the myth that scientists are a bunch of wild-eyed fanatics who do dangerous things and are oblivious to environmental concerns.

Don't Overlook Logistics:

What supplies and equipment will be available at the school and what will you have to bring? What must you do to reserve school equipment? How many students will you be working with, what size groups will they be in, and how many sets of supplies or equipment will you need? Are there enough electrical outlets available? How much time will you have to set up, clean up between groups, and pack up at the end? Will you provide name tags for the kids? (Calling them by name goes a long way toward building the relationships in which learning thrives.)

Think about these types of issues ahead of time and make the appropriate preparations. Remember that youngsters are easily distracted. Once you get rolling you don't want to disturb the continuity of your activity to hunt down something that you forgot — the attention of the students will likely be lost and you might have a difficult time refocusing them.

Presenting Your Activity

Well, the fateful day finally arrives — you get to go to the school and present your program. If you've done your homework you'll be well prepared with activities that should be both interesting and educational. But there's one more thing you need to know about: how to interact effectively with the students.

Working with students has a strong relational component. If they view you favorably, your chances of having a positive impact are substantially enhanced. You don't have to act like a kid to be liked by kids; in fact, many young people recognize such behavior as phony, and there's nothing worse you can do with kids than come across as phony. Their view of you will be strongly influenced by your attitudes toward them. Here are a few tips.

Be Excited and Fun to Be With:

If you're not excited about the activities that you're doing with them, it's unlikely that they will be either. But ***your excitement can spread to others. Don't be overly serious. Enjoy yourself! Smile and laugh some. It's contagious.***

Demonstrate That You Like Them:

One of the best ways to do this is to call them by name. They'll really be impressed if you do this outside of class when they're not wearing name tags.

Take an interest in them. Talk with them in the halls and at lunch time. Don't know what to talk about? That's great — you shouldn't be doing most of the talking, you should be listening. Ask them about their interests. Once you find out what interests them, continue asking questions that encourage them to share more about these areas. Don't ask questions that can be answered "yes" or "no," but open-ended questions, such as, "How did you get interested in ....? "What have been some of your favorite experiences,?" and "What things have required a lot of work or practice, but then have paid off?" Notice that there is a progression to these questions. They start out impersonal and non-threatening, and gradually enable the student to share more deeply of his or her experiences and feelings. Your part is mostly to listen and express interest. When they conclude that you're interested in them, they'll start to like you and pay attention to what you have to say.

Give Lots of Positive Feedback:

Set the students up to be successful, and when they succeed, praise them. Even mistakes can be dealt with creatively. When someone volunteers something that's incorrect, don't tell them that they're wrong; instead ask them why they think they're right. Frequently, in the process of explaining their logic to you or to the class they'll discover their own mistake — then you can praise them for their discovery. Or if they think their logic is correct, you can present your logic and have the class discuss and compare these two perspectives. If the class can't come to an agreement, try to develop and do an experiment to find out whose position is correct.

Then point out that this is how science really works: rather than scientists knowing all the right answers, they make hypotheses and do experiments to test them. The best scientists aren't those whose hypotheses are always right, but those who are willing to change their minds when the experiments disprove their hypotheses. Remember that developing these types of critical thinking and reasoning skills is at least as important as learning facts about particular science topics.

Don't Try to Impress Them:

If you try to blow the kids away with how much you know, you will succeed. However, you will also convince most of them that they could never understand or do science.

If you try to impress them with the elegance of theory, they'll go to sleep. The only people who appreciate theory are those who understand its applications.

And never, ever try to impress them with your coolness by putting down one of their classmates. The target of your "humor" will hate you forever. Feel free to poke fun at yourself, but never at one of them.

They will be most impressed with you if you simply demonstrate that you like them and help them to learn something.

Treat Them With Respect and Expect Them to Behave Responsibly:

If they start getting a bit rowdy explain your expectations to them and let them know that your continued interactions with them will depend on their behavior. Most kids will respond well to this. If not, deal with the problem students privately if possible, not in front of their peers. Criticize their inappropriate behavior, don't attack the people. For the most part, you should have an agreement with the teacher that he or she is responsible for dealing with classroom management issues. In general, I have found that most young people respond well to someone they know cares about them and places high expectations on them for responsible behavior.

Following Up

Now you've completed your first activity. Don't stop here or you will have lost at least two great opportunities. First, offer and provide follow up assistance to the teacher and/or students. Provide them with opportunities to read more about interesting applications of your topic, places they can visit to see applications happening (perhaps where you work; see "Conducting a Tour of Your Worksite"), or science fair projects they could do in this area. Encourage them to write follow-up letters to you sharing their comments and any questions they later think of. Then be sure to write back, taking the opportunity to reinforce a few main principles.

Second, have the teacher review your program, pointing out things that went well and things that could be improved. This will help you understand how to do an even better job next time.

Speaking of next time, don't forget to find out what topics they'll be covering in the next month or two, and make an offer for a return engagement. As you and the students get to know one another, your times with them will become increasingly productive. You will grow in your understanding of how to interact effectively with them, and they will become increasingly eager for your visits.

The middle school physical science teacher with whom I work uses my upcoming visits as a carrot. She tells the students, "When you demonstrate sufficient mastery of a topic, Dr. E will come for a day of related activities." She tells me that it works like a charm. And from the reactions of the kids when I show up, I believe it.

Best of all, I get to see their growing understanding of and excitement about science. Here's hoping you will too.

WORKING EFFECTIVELY WITH TEACHERS

Helping one or more teachers enhance the quality of their science instruction is a great way in which nearly any technical professional can enrich precollege education. There are several significant advantages to concentrating your efforts on teachers. First, since each teacher interacts with many students, the results of your efforts are greatly leveraged. Second, even after you are no longer directly involved, the enhanced teaching skills continue to impact students for years to come. Third, since our professional interactions are mainly with adults, communicating with teachers comes more naturally for many of us than does communicating with students. Finally, while working with students involves a substantial element of motivation, most teachers are eager to improve their knowledge, skills and effectiveness.

Pilot programs in which engineers and scientists have provided support to teachers have been quite successful. For such efforts to be productive, however, people on both sides must have realistic understandings of each others' backgrounds, strengths and limitations, and must be sensitive to and appreciative of one another. The purpose of this chapter is to help you understand how to interact effectively with teachers, and to suggest some ways in which you might help them enhance their science teaching abilities.

Things You Should Know About Teachers

Most people enter the teaching profession genuinely caring about kids and believing that teaching offers them a way to positively impact lives and improve society while earning a living. Along the way they undergo extensive training and become highly skilled professionals. Their work is very demanding, frequently frustrating, and often thankless, factors which sometimes lead to burnout. However, those who learn to cope effectively with imperfect people and bureaucracies, maintain their idealism and flexibility, remain positively focused on their students, and continue to grow in their teaching abilities often derive great satisfaction from their teaching careers.

Preparing for a teaching career involves studying a variety of topics: the theory and psychology of intellectual development, methods of teaching, the content of subjects to be taught, as well as most of the topics common to a well-rounded liberal arts curriculum. Student teaching must be completed prior to certification, and continuing education courses must sometimes be taken to maintain active teaching credentials. In addition, many teachers pursue graduate work — a master's degree is virtually required for teachers in many parts of the country.

The mix of courses taken by prospective teachers varies substantially depending on the age level of their intended students. Elementary education majors are typically required to take very little science. As a result, many elementary school teachers have very limited understanding of technical principles or applications and often avoid incorporating science topics into their classes.

Secondary teachers, on the other hand, are required to take numerous courses in their intended instructional area. As a result, high school science courses are usually taught by people with good understanding of the subject matter. Even outstanding high school teachers, however, are frequently unaware of many relevant applications and fascinating career opportunities that could be included to stimulate increased student interest in the science principles they are teaching. In addition, staffing constraints in some schools can result in teachers being assigned classes which are outside their area of expertise.

It is difficult to generalize about middle school teachers because in many regions they can have either an elementary or a secondary education background. As a result, they frequently exhibit a wide range of subject matter knowledge. You can best accommodate this on an individual basis, keeping in mind that the middle school teacher's primary task is to develop descriptive understanding of scientific principles in students who are just beginning to think abstractly.

On completing their training, teachers are typically filled with enthusiasm and creative ideas that they are eager to put into practice. Once in the classroom, their training is tempered with and strengthened by practical experience.

Unfortunately, their enthusiasm is often dampened by the discoveries that they have significantly less academic flexibility than they had anticipated and that many changes are difficult to implement. Funding limitations frequently prevent them from purchasing the books, support materials, and supplies needed to improve the curriculum. State departments of education dictate the competencies that each student must master in a given year, and local school boards often add further requirements. Standardized tests are often required for progress assessment, and teachers are pressured to ensure that their students perform well on these tests. Some teachers disagree with the priorities embodied in the mandated competencies and question whether the multiple-choice standardized tests provide a meaningful assessment of students' ability to think creatively and solve complex real-world problems. Nonetheless, they recognize the necessity of satisfying these requirements, and do their best to balance "teaching to the test" against providing motivational instruction in the areas they believe will best meet the long-term interests of their students.

While new teachers enter the classroom eager to work with students, many of them find classroom management and student interaction to be far more intense than they had expected. Providing focus, direction, and control for the normal exuberance of 20 to 35 active elementary school children over a six-hour period can be a challenge for nearly anyone. For middle and high school teachers, this is compounded by much larger numbers of students and the wide range of physical, social, and emotional changes that accompany the transition from childhood to adulthood. In addition, nearly all teachers have at least a few students whose serious personal or family problems require special empathy, attention, and counseling.

These "normal" challenges are compounded by a growing fraction of today's students who are undisciplined, uninterested, socially maladjusted, and sometimes openly hostile. Increasingly, our society expects schools and teachers to develop in students not only intellectual skills, but also to fulfill what has traditionally been the family's role of imparting good citizenship, self-discipline, values, and a host of other personal qualities (all without compromising anyone's individual freedom or offending their religious and moral beliefs, of course).

Teachers are also subjected to a wide range of responsibilities and time demands. In addition to their in-class teaching time, they must make time to help individual students who have questions or are progressing slowly, to lead school clubs or sports teams, to attend a variety of staff meetings, parent conferences and parent-teacher organization meetings, and to serve as monitors in halls, lunchrooms, and playgrounds. They must also review and grade homework, papers and tests from the previous day's classes, as well as prepare interesting and varied programs for the next day's classes, usually with no more than one free period per day. In all of these activities they are expected to comply with the varied, and sometimes contradictory, expectations and priorities of numerous parents, administrators, fellow teachers, and special interest groups.

All things considered, teaching is a demanding job — one that requires a lot of skill, hard work, sensitivity, and endurance. Most teachers are idealists who care deeply about kids and their educations. Considering the challenges inherent in their jobs, however, it's not surprising that some of them have their enthusi-

asm dampened or become burnt out along the way. If we are to interact effectively with teachers, we need to admire their idealism, appreciate their dedication to working under frequently difficult conditions, and respect them as highly skilled professional peers.

Ways You Can Help

So what are some of the things you can do to help teachers, particularly in the area of science? Before discussing specific options, it is worth reemphasizing a couple key principles from the overview chapter. The best way to help a teacher is to become a trusted friend and teammate who respects and is responsive to his or her expressed needs. Don't enter into your new relationship with a predetermined notion of what is needed or what you will do. Worse yet, don't insult the teacher's intelligence by assuming that teaching is easy, that it's a part-time job, or that he or she is doing it because they can't find a "real job". Instead, find out what the teacher is trying to teach, then help them do it with excellence. You can suggest some possible ways in which you might contribute (see below), but be sure to also solicit the teacher's ideas, and then let him or her be the judge of which option(s) you should pursue.

Help Teachers Implement Hands-On Discovery-Based Science Activities:
It's well known that students learn best not from textbooks or lectures, but from interesting activities in which they get to do hands-on experiments and discover key principles for themselves. Many courses, however, remain essentially devoid of meaningful hands-on activities and discovery experiences. You can help teachers implement such activities with their classes.

Worried that you don't have the creativity, education background, or time to develop these yourself? That's good, because lots of activities have already been developed, tested, and refined. These are almost always better than the ones that we scientists and engineers dream up. Brief descriptions of many sources of individual activities are provided in the chapter "Sources of Ideas for Hands-on K-12 Science & Math Activities." Help teachers become familiar with these, as well as with hands-on discovery-based programs that are being implemented at other schools.

Perhaps you could arrange for your employer, a group of local professional society chapters or a service group to establish a science education resource center for your community and purchase some of these materials to stock it. Then you could help teachers discover and use these resources in their classes. This should be done in close collaboration with the school system, which may already have a resource center that you could help strengthen. Be sure that the materials you purchase are pertinent to the curriculum and that you involve teachers in their selection. Otherwise they are likely to end up collecting dust.

Many hands-on activities require supplies and simple equipment. Schools frequently have very limited budgets for such purchases. Your resource center can make such items available. Some of them might have to be purchased, but many can be acquired by simply alerting local companies and technical professionals to the types of items that the school would find useful and asking that they donate surplus items to the resource center rather than discarding them.

Some supplies and equipment are typically available at the school, but are often poorly organized, not working, or not well understood by the teachers. You can help by inventorying these items, fixing them, and conducting seminars or writing instructions on how to use them.

Complete inquiry-based science curricula are even better than individual hands-on activities. Such curricula are becoming available from a number of suppliers, and are being adopted by an increasing number of school systems. You could help introduce your teacher contacts to these curricula and/or serve as an advocate for the adoption of such a curriculum in your community. (See "Sources of Hands-on Science & Math Activities — Category IV: Hands-on Science Curricula and Information for Teachers".)

These curricula typically provide everything that teachers need to lead their students in hands-on activities in which they discover key scientific principles for themselves. Background information, instructions, discussion guides, and even suggestions for assessing student progress are provided to the teachers. In addition, kits containing equipment, supplies and student guides provide everything needed for the entire class to conduct each activity. Classes are typically broken into pairs or small groups of students, so that everyone gets directly involved in each activity. In addition, each topic area is subdivided into 10 to 20 sequential activities which the students do over a period of a month or two. This facilitates the systematic development, application, and reinforcement of knowledge over an extended period. Perhaps most importantly, students experience the process of science as they are conducting these activities. This promotes the development of logical thinking skills in the context of their investigations of specific science topics.

Extensive information about these hands-on curricula are available from a number of sources, particularly the National Science Resources Center (NSRC) in Washington, DC. NSRC also has written materials and conducts periodic workshops for scientists and engineers to prepare them to become advocates for the adoption of such curricula in their local schools. Phi Delta Kappa also has an excellent booklet describing how these curricula can be used in elementary schools. (See "Key Organizations, Publications and Resources in Science Education Reform".)

Help Teachers Understand Technical Subject Matter and Its Applications:

Many elementary teachers are not only unfamiliar with science, they are intimidated by it. As a result, they avoid teaching it as much as possible. The good news is that most of them recognize their weakness in this area, are eager to improve, and welcome whatever assistance is available and proves to be useful.

One way you can contribute is to help elementary and middle school teachers become comfortable with the relevant principles and applications of science topics scheduled to be covered in their classes. This can be done one-on-one, but is even better in a group tutorial or workshop setting, provided various classes (or the entire school) coordinate their science curricula.

It is essential that you keep the discussion at a level that the teachers can clearly understand and enjoy and that is appropriate to the age level and interests of their students. Your efforts will be counterproductive if you reinforce their preconception that science is very hard and that one needs to have a Ph.D. to understand it.

A frequently effective format is to engage the teachers in a hands-on project — something that they can take back and use in their classrooms. ***Students learn best when they are actively involved in hands-on activities, and so do teachers.*** The most effective projects are ones that fit nicely into the curriculum and district requirements.

For example, if next month's science topic is magnetism, you could lead a teacher's workshop in which they do experiments to determine the effects of various parameter (wire length, voltage, and core material) on the strengths of electromagnets (how many washers or paperclips are picked up). Following this, you could answer questions the teachers have about magnetism, perhaps giving them a brief tutorial on magnetism. You could then provide them with the materials they need to conduct this activity with their students, as well as give them ideas for other possible activities.

Teacher workshops must be relevant and demonstrate how scientific principles are used in practical applications. For most people, teachers included, interesting and relevant applications provide the hook that stimulates initial interest in a topic. If your workshops concentrate totally on theory and underlying principles, they will be unmotivational and boring. If you couple scientific principles with interesting and relevant applications, your workshops will not only be much more interesting, they will also model a method for providing motivational science instruction to students.

These workshops should also be convenient to attend. This can be accomplished by having them at the school, free of charge, and reasonable in length (one hour to one day). Ideally, your company might pay for substitutes to enable the teachers to participate.

Printed background materials can also be developed, copied, and distributed to the teachers in conjunction with the workshop. Such assistance to the teacher has proven to be particularly effective when it is combined with exciting in-class student activities in which technical professionals reinforce the content being covered by the teachers (see the "Working Effectively With Students" chapter).

Familiarize Teachers With Career Opportunities Related to Science Topics:

While high school teachers usually have much less need for assistance with science content, they frequently need information on relevant applications and interesting career opportunities related to their subjects. You, your co-workers, and your company can provide this by means of periodic seminars, lab and/or plant tours, personal meetings, part-time or summer employment, or various combinations of these. In larger communities science teachers from all area high schools can be encouraged to take part in these activities.

Interactions with high school teachers can usually be carried on at a substantially higher technical level than is appropriate for elementary school teachers. They should, however, remain focused on the big picture and on relevant applications, rather than getting bogged down in technical details and esoteric issues.

Don't fall into the trap of thinking that only "the latest and greatest" applications will stimulate interest. ***Some of the most captivating topics are those that provide clear demonstrations of how scientific principles are used to solve scientifically "mundane" but socially relevant problems,*** such as increasing the crash resistance of cars, reducing or detoxifying hazardous waste, and so on.

Teachers are frequently interested in hearing about the nature of your work and what science principles are involved in it, particularly after you have developed good rapport with them. Explaining your work to them, however, usually isn't the best place to start.

Help Teachers Access Information and Expertise:

Teachers are often eager to supplement their classroom activities with interesting presentations, demonstrations, field trips, and other curriculum enrichment programs, but don't know where or how to find such assistance. In addition, they sometimes have: students with particular interests or questions who would benefit greatly from contact with specialists in the appropriate technical areas; students with ideas for science fair projects who need assistance, advice, or access to specialized knowledge or equipment; students who are struggling and need tutoring; female or ethnic minority students who need empathetic mentors and role models; and so on. Many individuals, companies, and professional societies would gladly provide these kinds of support, but don't know what or where the needs are.

You can help by linking the teachers and their needs with the appropriate individuals, groups, and resources in your community. Find out which people in your workplace or local professional society chapter are interested in supporting science education and ways in which they are willing to help. Then create and publicize a local mechanism to connect the needs with the resources. On a national scale, many professional societies are becoming

increasingly interested in K-12 education and are developing resources that could fit some of these needs. You can access these through your society's K-12 education coordinator, or the organizations listed at the end of the introductory chapter.

Help Teachers Understand and Do Activities That Develop Science Process Skills:

Specific content isn't the only thing that teachers and students need to learn about science. Perhaps even more importantly, they need to learn about the process of science: how hypotheses are constructed and tested, how information is evaluated and logical conclusions drawn from it, how risks are assessed in terms of probability and statistics, how priorities are set as a result of cost-benefit analysis, and so on.

While a relatively small fraction of today's students will need to know Newton's laws as adults, they all will need an appreciation for these science process skills in order to be intelligent shoppers and rational shapers of public policy. The alternative is a public that makes decisions based strictly on who has the slickest advertising or can make the most emotionally appealing argument.

You can help teachers recognize the importance of science process and engage their classes in activities that develop logical thinking skills. Experiments in which students have to think about what conclusions can be drawn from their observations are outstanding in this regard. ***You can help teachers learn to engage and lead their students in thinking through information, developing sound conclusions, and identifying faulty logic.*** Many individual activities and inquiry-based curricula lend themselves very well to such processes.

All of your talk about science process won't have much effect, however, if you inadvertently reinforce the misconception that scientists can provide correct answers to every question asked them. Admit to teachers that you don't know the answers to some questions, even in some cases where you do. One of the best ways to encourage teachers to engage in science process is to model it in the way in which you interact with them. Instead of providing answers to all their questions, engage them in simple experiments through which they can discover the answers for themselves. Guide them as they process data and observations, seeking to identify the appropriate conclusions. Help them see that not all experiments lead to a unique conclusion and eliminate all alternative hypotheses. Allow them to go down some blind alleys and struggle with confusing results, then tell them about how this also happens to you in your technical work. Encourage their understanding that negative results aren't necessarily failures since from them we also learn — in this case that we need to develop a different hypothesis. In short, guide them in experiences where they are *doing* science, and encourage them to do likewise with their students.

Help Teachers Engage Parents and the Community:

Many problems in U.S. education stem from society's tacit assumption that education begins and ends in the classroom and that teachers and schools are solely responsible for its success or failure. Imagine the educational impact of parents and children doing interesting projects and experiments at home to complement the science topics being covered in school. You could help organize such an effort through the parent-teacher organization and assist by either developing activities or accessing programs that are commercially available.

One of the reasons teachers hesitate to do hands-on discovery-based activities in class is that many of them require small groups each needing adult guidance. You could organize a program through which parents volunteer to serve periodically as classroom assistants to facilitate such activities.

How about working for the establishment of a hands-on science museum in your community, or helping teachers access an existing one? Or getting the Chamber of Commerce or a group of companies to provide financial support to send teacher representatives to science education training events, or provide rewards for teaching excel-

lence? Or getting your local Boy Scout, Girl Scout, or 4-H group involved in some exciting technology oriented events? The possibilities are limited only by your imagination!

Serve As An Advocate for District-Wide Reform of Science Education:

Are there teachers in your area who are doing hands-on inquiry-based science in their classrooms, but are having trouble getting this approach more broadly accepted in the district? You can provide a great service by actively supporting them at meetings with their principals, district administrators, and school boards. Tell these individuals that you learned science most effectively when you actually did it, rather than when you just read about it. Help them understand how students can learn skills such as logical thinking and teamwork in the context of inquiry-based science lessons. As a technical professional, your experiences and opinions carry a lot of weight with these policy making individuals and groups, particularly if you've also invested some of your time working with teachers or students and if you're knowledgeable about the constructivist reform movement. For help in this regard, contact the National Science Resources Center or the National Research Council (see list at the end of the overview chapter).

Getting Started and Interacting Effectively

These ideas represent only a few ways in which you can help teachers with science education. You can probably think of others. Why not present these and your own ideas to school teachers and administrators in your area, ask them to add their own thoughts, and determine those areas in which they would most like your help? Then follow up vigorously on their suggestions and watch the good things start to happen.

While you might want to have preliminary discussions with a teacher you already know, it is usually best for your first formal contact with a school to be with the principal. At this meeting you should indicate your interest, outline the wide range of ways in which you think you might contribute, and solicit official approval for your initiative. Assuming a favorable response, have the principal arrange a time for you to meet with the teachers, either all of them or a group of the most creative, flexible and proactive ones.

When you meet with the teachers, give a bit of personal background about yourself, describe how you became interested in supporting science education, and present a sampling of some of the ways that you think you might assist them. It might be good to give them a printed list of some of the ideas in this chapter plus some of your own thoughts. Take along a sample activity or kit to illustrate the types of resources that are available. Having them actually do an introductory activity can be very effective, provided it doesn't take too long. Perhaps you could leave some resource materials and supplies for them to look over or try out with their students — teachers love to get useful "freebies".

Keep your initial interaction as short as possible (25 minutes maximum), as teachers operate on tight schedules. Because they are so busy, one of the most effective points you can make is how your activities will either save them time or significantly enhance their classroom instruction for just a small investment of their time.

Solicit their questions, discussion, and initial reactions, but don't press them for a commitment at this point. As you leave, ask them to discuss your ideas among themselves, add their own, and prioritize them. Then set an appointment to meet again and get their feedback.

The purpose of the follow-up meeting is for the teachers to indicate whether they are interested in your assistance and how they think you can best help. Your job is mostly to listen and to clarify their priorities. Out of this discussion should come a mutual commitment to a plan of action and to a specific set of initial activities.

If additional meetings are needed to clarify details it would be good to schedule them for non-school hours. During the school day teachers' lives are filled with a myriad of activities and concerns, making it difficult for them to concentrate for extended periods on detailed planning. Brief meetings right after school usually work better than ones held during the school day.

You should also ask whether, before initiating activities, you can visit a class to observe a typical science lesson. This will give you some first-hand insight into how science teaching is approached, as well as give you and the teacher(s) an opportunity to get to know one another better before you start.

As emphasized in the overview chapter, it is important to recognize that your long-term impact depends critically on the development of positive interpersonal relationships. You can maximize your chances of doing this by treating the teachers as respected peers, responding to their expressed needs, following up on your commitments, giving them lots of encouragement and positive feedback, seeking their evaluation and constructive criticism of your efforts, and modifying your future efforts in response to their comments. ***In short, seek to work as a team with them,*** be flexible, and view yourself in a subservient role as a behind-the-scenes supporter. As you do this effectively you will gain their trust and respect, and win the right to be heard — even when your later comments involve suggestions for ways in which they can improve.

So what are you waiting for? Get involved! Start the ball rolling now! But commit yourself to sticking with it for the long haul — at least one year. Remember that all of the needed changes will not occur overnight. The effort to enhance science education is more like a marathon than a sprint. Your support will be a process rather than an event. But the results are well worth the effort!

CONDUCTING A TOUR OF YOUR WORKSITE

Taking students and/or teachers on a good tour of your worksite can be a very effective way to enhance science education. Such activities are highly motivational because they enable the participants to see science being applied in the real world. (For nearly everyone, applications provide the motivation for learning about principles, contrary to our traditional inclination to teach principles first, with applications to follow—maybe.) In addition, participants gain exposure to activities and equipment that could not be transported to their school, get to interact with engineers and scientists of different ages, genders, and ethnicities, and learn first-hand about various career opportunities.

Nearly anyone can conduct an interesting tour which has substantial educational value and is a rewarding experience for everyone involved — provided a few basic principles are followed. If these principles are ignored, however, a tour can be a boring experience in which the student and teacher participants are discouraged from future interest in science, and the engineers experience frustration rather than satisfaction. So read carefully the guidance offered here, and be sure that your tour is designed and conducted according to these simple, but very important, principles.

The two most important principles in conducting an effective tour are:

1. ***Engage the participants in activities, rather than just showing them things and talking to them.***
2. ***Deal with subjects and examples that the participants can understand and relate to, rather than blowing them away with topics, examples, or technical jargon that few of them relate to or understand.***

Engaging Participants in Activities

Almost everyone finds doing things more interesting than just seeing things, or worse yet, simply hearing about things. The most common mistake that we professionals make in conducting tours is to conduct them in a "show-and-tell" format. The reaction is predictable; in the parlance of the kids, "it's booooring." Don't fall into this trap.

Instead, design your tour to involve the participants in activities — operating equipment, conducting experiments, making measurements, solving problems, and the like. Use these activities as simplified examples of the types of work that you and your co-workers do.

For example, in touring a scanning electron microscopy (SEM) lab, each participant should have a (brief) chance to operate the instrument rather than just hearing about the instrument and watching someone else operate it. This requires some planning and preparation, and consideration of such questions as: How large a group can you accommodate? Will each person operate the instrument individually or in groups where each person has a particular job (sample mover, focuser, magnification changer, photo taker)? How will the appropriate controls be identified and participants be discouraged from inappropriate knob twiddling? What types of specimens should be examined? What will other students be doing when not operating the microscope? Who will supervise the microscope and other activities? And so on.

The best activities are ones in which participants solve a mystery, which can frequently be posed as a detective problem, or engage in experimentation, measuring the effects of changes in one variable on some other parameter. This helps them understand the process of science, as well as engaging them in activities with interesting materials and equipment.

The most common reservations scientists and engineers express about conducting activity-oriented tours are that the time used doing activities prevents the participants from seeing as much of the worksite as they could in a more conventional "show-and-tell", and that activities require more thought and preparation. Both of these points are correct. But which is more important to you — showing off your whole facility in a way that is boring and will be quickly forgotten, or involving the participants in an exciting and memorable experience, albeit less broad? Once you get past the trauma of not showing off everything, you'll be free to select the few things that lend themselves best to interesting activities. And while activity oriented tours do require more thought and preparation, the payoff in participant enthusiasm and learning make the effort well worth it — just ask any of us who have quit doing show-and-tells.

If you have a good slide show or videotape that presents an overview of your facility or shows exciting activities that would be impossible for participants to be involved in, show it prior to or following your activity. But be sure that it's brief!

Being Age Appropriate

In order to be successful, activities must be understandable and interesting. The other common mistake we professionals make in conducting tours is to deal with things that are difficult to understand, because they are too complex or not sufficiently visual, because examples are used that the participants can't relate to, or because confusing technical jargon is used.

To avoid these pitfalls, first, avoid the temptation to focus your tour on particular issues, phenomena, or equipment just because your professional contemporaries find them interesting or impressive. You might have the greatest ion beam accelerator on earth, but it's unlikely to excite a group of fifth graders because they can't see it do anything and they don't even know what ions are.

Instead, ***select things that are highly visual and will excite kids of the age you are working with.*** Sometimes the best things are those we overlook because of their simplicity and our familiarity with them. The incidental equipment and supplies of our labs — voltmeters, oscilloscopes, hardness testers, microscopes, liquid nitrogen, etc. — can be fascinating for kids when they are incorporated into a good activity.

Many times, activities with simple equipment can be used to help students understand more complex processes. For example, since seventh graders are not familiar with integrated circuits, they are not likely to have much appreciation for photolithography. On the other hand, using cameras to reduce spy messages to fit under a postage stamp and enlargers to subsequently print and read them provides an exciting vehicle for illustrating the principles of photolithography in a way they can relate to. It also sets you up to describe how photolithography enables the miniaturization of electronic circuits.

Second, in selecting examples, use ones that the participants understand and can relate to. For a scanning electron microscope demonstration, "familiar" samples such as fruit flies, light bulb filaments, Velcro, etc., are better than "foreign" samples such as integrated circuits and fracture surfaces.

Finally, go over your explanations ahead of time and eliminate all nonessential or inappropriate theory and complexity. Fifth graders don't need to know about secondary electron and x-ray generation in order to look at fruit flies and gain an appreciation for scanning electron microscopy. On the other hand, high school chemistry or physics students should be able to appreciate these concepts in conjunction with activities involving microanalysis.

Similarly, you should carefully scrub your explanations of technical jargon and acronyms. Call the CRT the video tube, the SEM the scanning electron microscope, and so on. For younger children it is particularly important that you simplify your vocabulary — in an SEM lab tour, refer to focusing as sharpening the picture, and to changing the magnification as making the picture bigger or smaller. Again, forethought and planning is required, but the dividends are well worth it.

Other Suggestions

In addition to these two most commonly violated principles, there are several other issues worthy of your attention.

Teachers should be involved in every stage of the process. When included in planning the tour teachers can contribute in a multitude of ways: by helping plan activities that integrate effectively into areas the students are currently studying, by helping you understand the level of the students' understanding and vocabulary, by introducing the students ahead of time to the type of work you or your company does, and by providing background that will better prepare the students for the activities they will be experiencing.

After your plan is formulated it might be helpful to do a dry run of your tour with the teacher. Let him or her know that you want the tour to be an outstanding experience, and that constructive criticisms, rather than offending you, will be appreciated as a means of helping you to reach that goal. Be sure that the teacher is also present during the tour, and knows that you want him or her to point out to you ways in which you are missing the mark ("The CRT — is that the video tube?")

Finally, after the tour is over, get feedback from the teacher on what parts were most effective and how other parts could be improved. By acting on the teacher's suggestions you can continually improve your tour.

Make sure that you carefully plan the logistics ahead of time. Consider issues such as: What safety equipment should be available? What areas should be closed off? How many adult assistants will be required and what preparation do they need? What supplies will be needed? What things can go wrong and what provisions should be made for these eventualities? It's also a good idea to have name tags available so that you can call everyone by name.

During the tour I take advantage of opportunities to relate how what the participants are currently learning in their classes will pay off later and to encourage them to be diligent in their studies. This can often be worked into a closing statement. For example: "When I was in seventh grade and learning for the first time about atomic bonding I couldn't understand why I had to learn that stuff. It didn't seem that I'd ever need to know it. Now I use it everyday to figure out how to control the properties of materials, just like we've been doing in our experiments today. That enables me to have a really interesting job and also to earn a good salary — a tough combination to beat. If you work hard in school it will pay off in similar ways for you."

Try to ***provide some materials and/or follow-up activities that can be taken home or back to the classroom*** as a remembrance or to reinforce and/or extend the primary principles dealt with on the tour. You might, for instance, give the class a poster showing different parts of the fruit fly that the students photographed using the scanning electron microscope.

Finally, have fun and be fun to be with. One of the stereotypes worth destroying is that engineers and scientists are a dull and serious bunch who care only about inanimate objects and rarely have any fun. Hopefully that's not you. Your attitude will likely be contagious — either way.

SOURCES OF HANDS-ON K-12 SCIENCE & MATH ACTIVITY IDEAS

Following are brief descriptions of available resources containing ideas for hands-on science and math activities which teachers or other interested adults could use with K-12 students. They have been evaluated and recommended by scientists and engineers who are engaged in science and math education enrichment programs.

This listing is by no means inclusive. If you have used other outstanding materials which you believe should be considered for addition in future printings, please list and describe them on the Reader's Questionnaire at the end of this guide.

Note regarding costs: Only the approximate costs of these resources are included. The terms "inexpensive, modestly priced, and more expensive" imply costs of less than $10, between $10 and $25, and more than $25, respectively.

Category I
Fully Developed Single Session Activities:

These resources contain activities which could be used with little or no modification for complete single session programs lasting one class period. Typically, they are fully developed stand-alone programs in which the students perform experiments, make measurements, record and analyze data, and develop conclusions about the pertinent scientific principles. Scientists or engineers could either conduct these activities with the students or help teachers become familiar with and integrate these hands-on activities into their instruction.

Lawrence Hall of Science
University of California
Berkeley, CA 94720
(510) 642-1016

Lawrence Hall of Science has produced a very large number of fully developed science and math activities for use with elementary and middle school students. Activities cover the full spectrum of life science, earth science, physical science, chemistry, astronomy, math, etc. These have been developed by a staff of educators and museum personnel specifically to provide high quality educationally sound resources for use by teachers. Many of the activities are available as inexpensive to modestly priced written materials which require only inexpensive readily available supplies. Other activities require more expensive kits of equipment and supplies which can be purchased from LHS. Training seminars on use of specific LHS materials are available at the museum in Berkeley. A free catalog, titled "Eureka", is available. Activities in the SAVI/SELPH, GEMS, and SEPUP programs are particularly good.

AIMS Foundation
P.O. Box 8120
Fresno, CA 93747
(209) 255-4094

AIMS has published about 20 modestly priced books each containing approximately 25 fully developed science and math activities for use with elementary and middle school students. Each book emphasizes a particular topic area relating to life science, earth science, physical science, or math, and concentrates on a particular student age range. Most of the activities were developed by teachers and use readily available inexpensive supplies. Detailed descriptions and student work sheets are included for most activities. Limited numbers of free copies can be made for classroom use, and unlimited copying rights can be purchased. Local representatives will conduct training seminars on how to conduct AIMS activities. A catalog is available.

Operation Physics

American Institute of Physics
1825 Connecticut Ave. NW, Suite 213
Washington, DC 20009
(202) 232-6688

AIP has trained and equipped teams of science educators in each state to enable elementary and middle school teachers to conduct hands-on physical science activities with their students. These Operation Physics teams conduct local teacher workshops on topic areas including light, color and vision; sound; electricity and electric circuits; magnets and magnetism; states of matter; forces and fluids; forces and motion; simple machines; heat and energy; measurement; and astronomy. The trainers have as resources substantial numbers of fully developed hands-on activities in each of these topic areas. These activities were developed by teams made up of university and high school physics teachers, elementary science specialists, and 4th-6th grade teachers. Each activity includes teacher instructions and student activity sheets, as well as a list of the readily available supplies needed. AIP has agreed to give interested scientists and engineers access to these program materials and ideas through their local Operation Physics trainers. Call AIP for the name, address and telephone number of the trainer in your area.

3-2-1 Contact

Children's Television Workshop
One Lincoln Plaza
New York, NY 10023
(212) 595-3456

The Children's Television Workshop (producers of Sesame Street) have developed a series of 30 programs for upper elementary and middle school students dealing with various issues involving science, technology and society, (for example, trash and recycling). Each program consists of a highly professional 15 minute videotape (narrated by kids), plus a teachers guide with instructions for two 40 minute lessons. Individual topics can be purchased for a modest fee; the entire set costs several hundred dollars. A modestly priced monthly magazine is also published. A free catalog is available.

TIMS (Teaching Integrated Math & Science)

University of Illinois at Chicago
P. O. Box 4348, Mail Code 250
Chicago, IL 60680
(312) 996-2448

TIMS provides approximately 50 fully developed math-related hands-on activities for elementary and middle school students which emphasize the scientific method and relationships between variables. Students identify variables, collect and graph data, make predictions from their data, and do additional experiments to verify their predictions. Topics such as measurement error, scatter in data, proportionality, and extrapolation are developed in the context of group problem solving. These materials were initially developed and used by university scientists and mathematicians in an outreach program with public schools. Based on their success they have more recently been

adopted and used by teachers. The materials contain detailed activity descriptions and student work sheets. Individual activity plans are inexpensive and limited numbers of free copies can be made for classroom use. Only inexpensive supplies are required. A free catalog is available.

Science Activities in Energy

Office of Scientific & Technologic Information (OSTI)
P.O. Box 62
Oak Ridge, TN 37831
(615) 576-1305

Science Activities in Energy provides fully developed activity outlines for upper elementary, middle school, and high school students in several energy-related areas, such as conservation, energy storage, chemical energy, electrical energy, solar energy, wind energy, etc. Each packet contains 10 to 30 detailed activity outlines as well as student work sheets. Some of these are available in Spanish. These were developed by the staff of the American Museum of Science and Energy in Oak Ridge and are available at no cost. The activities use inexpensive and readily available supplies. Unlimited copies can be made for distribution to teachers and students.

Institute for Chemical Education

University of Wisconsin - Madison
1101 University Avenue
Madison, WI 53706
(608) 262-3033

ICE has several modestly priced resources in the area of chemistry. Fun With Chemistry contains detailed descriptions and student work sheets for more than 50 activities for use at various age levels from elementary through high school. Hands-on Chemistry contains ten activity ideas for elementary aged children to do at home with their parents or other adults. Chemistry Camp describes how to conduct a week-long summer program for middle schoolers. These activities were developed by teachers and, for the most part, use inexpensive and readily available supplies. The materials are copyrighted, but limited copies may be made for teacher or student use. Training workshops are conducted regionally. A free newsletter is also sent to those who request to be on the ICE mailing list.

LESSON Program

Lawrence Livermore National Laboratory
Science Education Center, L-793
P.O. Box 808
Livermore, CA 94550
(510) 373-0778

The LESSON Program contains public domain outlines for fully developed elementary school activities dealing with a wide variety of science topics. More than 40 activities are available relating to topics from the disciplines of life science, chemistry (mostly as it relates to earth science), and physical science. These activities were developed and used by scientists and engineers in a science enrichment program for elementary school students. Workshops are available on how to conduct these activities effectively. The material contains detailed activity descriptions, but not student work sheets. Most use readily available supplies, but some require home workshop construction of simple equipment. A kit containing all of the supplies needed to do these activities is available for several hundred dollars from Delta Education, 1-800-258-1302. Unlimited copies can be made for distribution to teachers and students with LLNL permission.

National Engineers' Week

1420 King Street
Alexandria, VA. 22314
(703) 684-2852

Each February the National Engineers' Week Committee encourages engineers to conduct in-class science activities in their local schools. A packet of materials including a number of fully developed hands-on activities is provided to interested engineers.

Category II
Briefer Demonstrations and Activities:

These resources contain ideas for briefer demonstrations or activities which require less than a full class period, but could be integrated with other ideas into more complete programs. In many cases the activities are described only briefly, leaving more of the fleshing out process to the adult leader. Scientists, engineers or teachers could use these ideas to demonstrate particular phenomena as portions of more complete programs.

(Science) for Every Kid — 101 Experiments That Really Work

Janice VanCleave
John Wiley & Sons, 1989 - 1991

This is a series of 6 modestly priced books. Individual books deal with math, earth science, astronomy, biology, chemistry, and physics, respectively. Each book includes brief outlines (not detailed descriptions) of over 100 activities and projects for upper elementary and middle school students. Most of these are not fully developed experiments in which students record and analyze data, but interesting activities in which students learn about scientific principles by "guided messing around". These activities were developed and tested by teachers and edited by the author, who is an award winning teacher. Most of them use readily available supplies.

175 Science Experiments to Amuse and Amaze Your Friends

Brenda Walpole, 1988
(also 175 More Science Experiments ..., Terry Cash, Steve Parker and Barbara Taylor, 1989)
Random House, New York, NY

These two modestly priced books each contain 175 ideas for elementary school level science demonstrations and activities. The contents are brief outlines (not detailed descriptions) of activities in various areas of physical and earth science. Most of these are not fully developed experiments, but interesting activities in which students learn about scientific principles by "guided messing around". They were developed by authors of numerous books on science activities for children. Most of them use readily available supplies.

Invitations to Science Inquiry

Tik L. Liem
Science Inquiry Enterprises
14358 Village View Lane
Chino Hills, CA 91709
(714) 590-4618

This book outlines over 400 demonstrations and hands-on activities for upper elementary and middle school students. These activities cover a wide range of topics in physical, earth, and life sciences using readily available supplies. Most are demonstrations in which the students' curiosity is aroused by observing counterintuitive or sur-

prising results. They were developed and compiled by a professional educator. Videotapes demonstrating the effective use of these ideas are also available. This book (as well as the accompanying videotapes) is more expensive than some resources, but contains a large number of high quality activity ideas.

Idea Bank Coalition

Irwin Talesnick
S17 Science Supplies and Services Co. Ltd.
Box 1591
Kingston, Ontario, Canada K7l 5C8
(613) 544-6548

This book outlines over 600 science teaching ideas, many of which are hands-on activities, for use with elementary through high school students. They cover a wide range of topics in physical, earth, and life sciences using readily available supplies. The activities were developed and submitted by teachers and originally published in several educational periodicals. Limited numbers of free copies can be made for classroom use.

Chemical Demonstrations

Bassam Z. Shakhashiri
University of Wisconsin Press
114 North Murray St.
Madison, WI 53715-1199

Four modestly priced books each provide detailed descriptions of dozens of chemistry demonstrations (not hands-on activities) for use with high school and college students.

The Exploratorium Science Snackbook

The Exploratorium
3601 Lyon Street
San Francisco, CA 94123
(800) 359-9899

This modestly priced book contains teacher-developed descriptions of how 100 hands-on science museum exhibits can be modified, built, and used to illustrate physical science principles in classroom situations. The emphasis is on middle and high school students, but some are also applicable to upper elementary school.

Wonderscience

American Chemical Society (jointly with AIP)
1155 Sixteenth St. NW
Washington, DC 20036
(202) 452-2113

Wonderscience is a periodical published 8 times yearly to provide physical science activity ideas for upper elementary students to do with adult guidance and supervision. Each issue contains 4 or 5 activities built around a topical theme (e.g., reflection, friction, static electricity, etc.). These activities are developed by professional educators on the staffs of ACS and AIP. Most of these are not detailed experiments in which students record and analyze data, but fun activities in which students learn about scientific principles by "guided messing around". Subscriptions are inexpensive and selected back issues are available.

333 Science Tricks & Experiments
(also 333 More Science Tricks & Experiments)
Robert J. Brown
Tab Books, Blue Ridge Summit, PA

These modestly priced books each contain many ideas for science demonstrations and activities appropriate to upper elementary and middle school students. The contents are very brief outlines (not detailed descriptions) of activities in various areas of physical science and earth science, along with brief explanations of the pertinent phenomena. Most of them use readily available supplies.

700 Science Experiments for Everyone
United Nations Educational, Scientific, and Cultural Organization
Doubleday, New York, NY

This modestly priced book contains very brief descriptions of science demonstrations and activities appropriate to upper elementary, middle school, and beginning high school students. The activities deal with various areas of life science, earth science, and physical science and use readily available supplies.

Mr. Wizard's 400 Experiments in Science
Don Herbert & Hy Ruchlis
Book Lab
500 74th Street, Bergen, NJ 07047

This inexpensive book contains very brief descriptions of physical and life science activities for upper elementary and middle school students. All of them use readily available supplies.

Science on a Shoestring
Herb Strongin
Addison-Wesley, New York, NY

This modestly priced book contains over 50 ideas for hands-on science activities appropriate for upper elementary students. The activities deal mostly with physical science principles, but are organized by application under the major categories of matter, change, and energy. Fairly detailed descriptions of each activity are given, as well as a "script" and suggested discussion questions. The activities use readily available supplies.

Scienceworks
Ontario Science Center
Addison-Wesley, New York, NY

This inexpensive book contains 65 ideas for science tricks and demonstrations for elementary and middle school students. The contents consist of fairly detailed descriptions of general science activities which use readily available supplies.

Science Magic for Kids
William R. Wellnitz
Tab Books
Blue Ridge Summit, PA

This inexpensive book contains 68 ideas for science activities appropriate for elementary school students. The contents consist of fairly detailed descriptions of general science activities, as well as very brief explanations of the pertinent phenomena. All of the activities use readily available supplies.

Category III
Multiple Session Activities:

These programs require more than a single session to complete. They include multi-unit programs in which each activity builds on the previous ones, and individual or team projects which are carried out over weeks or months. Scientists or engineers could in some cases work directly with the students by conducting activities and assisting with projects, and in other cases serve less directly as sponsors or advisors.

A World in Motion

Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096
(412) 776-4841

SAE provides a kit containing two phases of activities on physical science, technology, and math exploration for students in grades 4-6. In phase one, student "design teams" engineer projects through scientific experimentation, math, and problem solving. This lasts seven class sessions, one hour each. Phase two includes 15 (per grade) individual hands-on experiments which supplement phase one activities. This program was developed for SAE by teachers, education consultants, and engineers. They make use of readily available supplies. Detailed activity descriptions are provided, but not student work sheets. All materials, including a videotape, are reproducible. Kits are sent at no cost to engineers or scientists who are willing to work together with teachers and students in the classroom. Promotional materials are also available to organizations interested in encouraging their members to form such educational partnerships.

International Science and Engineering Fair

Science Service
1719 N Street NW
Washington, DC 20036
(202) 785-2255

K-12 students conduct science related projects which are judged locally, regionally, and nationally. Volunteers can mentor students in designing projects and conducting experiments, provide tours and field trips to local industries, and serve as judges.

Science Olympiad

5955 Little Pine Lane
Rochester, MI 48064
(313) 651-4013

K-12 students work in teams on science related projects in preparation for local, state, and national competitions. Volunteers can serve as coaches, judges, or in various organizational capacities.

Odyssey of the Mind

P.O. Box 27
Glassboro, NJ 08028
(609) 881-1603

School teams solve two engineering or performance problems: one spontaneous and one long-term. Volunteers can serve as coaches, judges or contest organizers.

Young Scientists and Engineers

P.O. Box 3084
Sierra Vista, AZ 85636-3084
(602) 458-1560

K-12 students conduct after-school science and engineering projects. Volunteers can develop project ideas, provide technical assistance to the students, support performance-based competitions, or serve in various organizational roles.

National Engineering Design Challenge

Junior Engineering Technical Society
1420 King Street, Suite 405
Alexandria, VA 22314
(703) 548-5387

High school students design and build a "product" to meet a specific engineering need. Volunteers can help develop problems, serve as mentors to student groups, and conduct post-competition student programs.

U.S. Skill Olympics

Vocational Industrial Clubs of America
P.O. Box 3000
Leesburg, VA 22075
(703) 777-8810

Vocational students participate in competitions in 40 technical / vocational areas. Volunteers help organize and staff local competitions and serve as judges.

Mathcounts

1420 King Street
Alexandria, VA 22314
(703) 684-2831

Middle school students participate in math competitions similar to athletic events. Volunteers can coach teams and serve in various organizational capacities.

Community Computers Learning Centers

American Association for the Advancement of Science
1333 H Street NW
Washington, DC 20005-4792
(202) 326-6670

This program provides middle school math activities for students and their parents, teachers and counselors. Volunteers lead computer classes or workshops, teach math or science using hands-on materials, make presentations, etc.

Operation Smart

Girls' Clubs of America
30 East 33rd Street
New York, NY 10016
(212) 689-3700

Girls are involved in hands-on experiences, building and taking things apart, questioning and predicting, and developing an understanding of what scientists do. Volunteers can assist with hands-on activities, provide field trips, and serve as mentors.

Category IV
Hands-on Science Curricula and Information for Teachers:

These resources are systematic curricula based on hands-on inquiry-based activities, as well as information on novel approaches to science education. They are ideal for sharing with teachers who have become excited about the discovery-based approach and want to pursue it as their primary teaching approach.

Science and Technology for Children (STC)

Developed by: National Science Resources Center
Smithsonian Institution
Arts & Industries Building, Room 1201
Washington, DC 20560
(202) 357-2555

Distributed by: Carolina Biological Supply Company
2700 York Road
Burlington, SC 27215
1-800-334-5551

This program consists of a series of 24 inquiry-centered curriculum units for students in grades 1-6. There are 4 units per grade level covering key topics in the areas of life science, earth science, and physical science. Each unit consists of approximately 15 sequenced activities on a topical theme, e.g., electric circuits. These activities are designed to be done over an 8-week period in pairs or small groups. Emphasis is placed on developing science content and science process skills in the context of age-appropriate investigations. Teacher's books include teaching strategies and classroom tips, activity instructions, assessment materials, suggestions for linkages to other subjects (math, language arts, social studies), and a bibliography of resources for teachers and students. Student work books are also available, as well as kits containing all of the equipment and supplies needed for a class of 30 students. A free brochure is available which describes the program in greater detail.

Full Option Science System (FOSS)

Developed by: Lawrence Hall of Science
University of California
Berkeley, CA 94720
(510) 642-8941

Distributed by: Encyclopedia Britannica Educational Corporation
310 S. Michigan Ave.
Chicago, IL 60604
1-800-554-9862 ext. 6554

This program consists of a series of 27 inquiry-centered curriculum units for students in grades K-6. There are 5 kindergarten units, 6 units for grades 1/2, and 8 units each for grades 3/4 and 5/6. These cover key topics in the areas of life science, earth science, physical science, and scientific reasoning/technology. Most units consists of 4 sequenced activities on a topical theme, e.g., levers and pulleys. These activities are designed to be done over a 4 to 6 week period in small collaborative groups. Emphasis is placed on developing science content and science process skills in the context of age-appropriate investigations. Teacher's books include background information on the topic area, an overview of unit teaching goals and strategies, activity instructions, duplication masters of pages for student collection and plotting of data (in both English and Spanish), assessment materials, and a bibliography of multimedia enrichment options. Kits containing all of the equipment and supplies needed for a class of 32 students are also available. A free brochure is available which describes the program in greater detail.

Insights

Developed by: Education Development Center
55 Chapel St.
Newton, MA 02160
1-800-225-4276 ext. 2430

Distributed by: Optical Data Corporation
30 Technology Drive
Warren, NJ 07059
1-800-524-2481

This program consists of a series of 17 inquiry-centered curriculum units for students in grades K-6. There are 4 units for grades K/1, 5 units for grades 2/3, 5 units for grades 4/5, and 3 units for grade 6. These cover key topics in the areas of life science, earth science, and physical science. Units consists of approximately 15 sequenced activities on a broad topical theme, e.g., habitats of living things. These activities are designed to be done over a 6 to 8 week period in small collaborative groups. Emphasis is placed on developing science content and science process skills in the context of age-appropriate investigations. Teacher's books include background information on the topic area, an overview of unit teaching goals and strategies, activity instructions, duplication masters of pages for student collection and plotting of data as well as home-school work assignments, assessment materials, and a bibliography of supplementary resources including books for students and teachers, audiovisual materials, software, and organizations which supply free or inexpensive enrichment materials. Kits containing all of the equipment and supplies needed for a class of 30 students are also available. A free brochure is available which describes the program in greater detail. A follow-on middle school curriculum is also available.

Science Plus: Technology and Society

Developed by: Atlantic Science Curriculum Project
University of New Brunswick
Fredericton, New Brunswick, Canada

Distributed by: Holt, Rinehart and Winston, Inc.
151 Benigno Blvd.
Bellmawr, NJ 08031
1-800-426-0462

This program consists of 3 levels of inquiry-centered curriculum for middle school students. Each level is intended to be a year long study of 8 interdisciplinary topical units covering key areas of life science, earth science, and physical science. The units each consist of 4 to 12 sequenced lessons on a broad topical theme, e.g., oceans and climates. These lessons are designed to be done over a one month period. Each unit involves a combination of reading, exploration activities done in collaborative groups, analysis, discussions, and writing assignments. Emphasis is placed on developing science content and science process skills in the context of relevant applications. The Teacher's Annotated Edition and Resource Binder for each level contain overviews of each unit's teaching goals and strategies, suggestions for exploration activities, master copies of unit worksheets, teaching transparencies, a guide to materials needed for each activity, assessment materials, and extensive information on supplementary resources. Student books contain minimal text, but numerous suggestions for discussions, activities, and analysis through which students develop their thought processes and understandings of scientific phenomena. Supplementary videodisks specifically designed to complement this curriculum are also available.

National Diffusion Network

Office of Educational Research & Improvement
U. S. Department of Education
555 New Jersey Avenue
Washington, DC 20208
(202) 357-6134

The National Diffusion Network provides funding to assist with the dissemination of outstanding educational programs from the schools in which they were developed to other schools. Typically, this involves major curriculum elements, rather than individual activities. This won't provide information on specific activities, but helps teachers and schools access exemplary programs.

READER QUESTIONNAIRE

Please circle the most appropriate number for each question using the following scale:

5 = Outstanding
4 = Very good
3 = Good
2 = Fair
1 = Poor
0 = Didn't read, not applicable

How useful / helpful did you find each of the chapters to be?

5 4 3 2 1 0 Science Education: Things You Need to Know Before Getting Involved
5 4 3 2 1 0 Working Effectively With Students
5 4 3 2 1 0 Working Effectively With Teachers
5 4 3 2 1 0 Conducting a Tour of Your Worksite
5 4 3 2 1 0 Sources of Hands-on Science and Math Activity Ideas

How clear / readable did you find each of the chapters to be?

5 4 3 2 1 0 Science Education: Things You Need to Know Before Getting Involved
5 4 3 2 1 0 Working Effectively With Students
5 4 3 2 1 0 Working Effectively With Teachers
5 4 3 2 1 0 Conducting a Tour of Your Worksite
5 4 3 2 1 0 Sources of Hands-on Science and Math Activity Ideas

How accurate / appropriate did you find each of the chapters to be?

5 4 3 2 1 0 Science Education: Things You Need to Know Before Getting Involved
5 4 3 2 1 0 Working Effectively With Students
5 4 3 2 1 0 Working Effectively With Teachers
5 4 3 2 1 0 Conducting a Tour of Your Worksite
5 4 3 2 1 0 Sources of Hands-on Science and Math Activity Ideas

What, in your opinion, are the greatest strengths of this guide?

What, in your opinion, are the greatest weaknesses or deficiencies of this guide?

How has your program (or program plan) changed as a result of reading this guide?

What suggestions for changes would you recommend in future editions?

Name (optional): _____
Address (optional): _____
Phone (optional): _____

Please return completed questionnaire to:

Kenneth H. Eckelmeyer
Sandia National Laboratories, Mail Stop 0343
P. O. Box 5800
Albuquerque, NM 87185
FAX: (505) 844-7910